THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS™

SCIENCE ENVIRONMENT TECHNOLOGY TRANSPORT HISTORY SPACE

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FROGS

GET UP CLOSE WITH AMAZING AMPHIBIANS

INSIDE iPHONE 5

The technology packed in Apple's most powerful phone revealed

THE INTERNET EXPLAINED

Find out how over 2 billion users access our global computer network

EXTREME WEATHER

DISCOVER THE PLANET'S FIERCEST CLIMATIC EVENTS EVER

FIRE DEVILS / MEGA TORNADOES / LIGHTNING
HABOOBS / ICE STORMS / TYPHOONS & MORE

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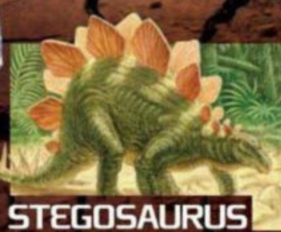
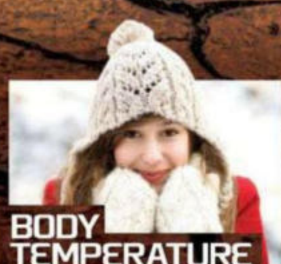
THE NEXT GENERATION OF AUTOMOTIVE TECHNOLOGY



STEGOSAURUS

How did this heavily armoured dinosaur live?



BODY TEMPERATURE

Why do we maintain our inner thermostat at 37°C?

20 STAR FACTS

Your stellar questions answered by our experts

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ISSUE 40

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FEED YOUR MIND!

In the grand scheme of things this ball of rock that we call home is a pretty nice place to live. We're just where we need to be in terms of being close enough to the Sun to sustain life, keep warm, and ensure we have water to drink and an atmosphere to breathe. However, these life-giving qualities are also the reason for the most extreme climatic conditions, including a perpetual lightning storm in Venezuela and super-strength gales such as those wrought by the devastating Hurricane Katrina. Indeed, from space our planet may look like a peaceful place, but our atmosphere can work itself up into a frenzy. This month we've taken some of the most bizarre instances of 'freak' weather ever to occur on Earth – like this year's Australian fire tornado and the deadly ice storm of 1998 in North America – and revealed the unique factors that led to each event.

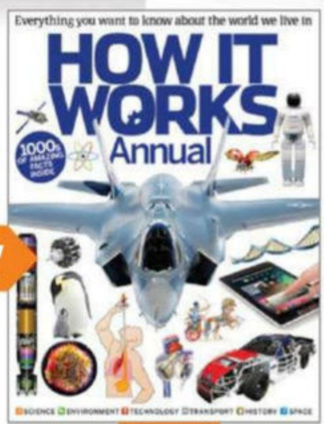
Also this issue discover the colossal infrastructure and technology behind one of the most pervasive inventions of all time: the internet. Where would we be without it?

Enjoy the issue.

Helen

Helen Laidlaw
Editor

THE WORLD OF HOW IT WORKS



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Meet the team...

Dave
Ed in Chief
This issue's internet feature sheds light on a global tool most of us use every day without a second thought.

Robert
Features Editor
My highlight was digging up Edison's original patent for his 1880 light bulb as part of this issue's Milestones piece.

Ben
Features Editor
When you live in a temperate country, the case studies in 'Extreme weather' may have happened on another planet!

Adam
Senior Sub Editor
I enjoyed exploring China's Forbidden City – I've often thought of the **HIW** office as a Hall of Mental Cultivation...

The sections

The huge amount of info in each issue of **How It Works** is organised into these sections:

ENVIRONMENT
The splendour of the natural world explained

TRANSPORT
Be it road, rail, air or sea, you'll find out about it in Transport

HISTORY
Your questions about how things worked in the past answered

SCIENCE
Explaining the applications of science in the contemporary world around us

TECHNOLOGY
The wonders of modern gadgetry and engineering explained in depth

SPACE
From exploration of our Solar System to deep-space adventures

WITH THANKS TO...

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CONTENTS

The magazine that feeds minds!

MEET THE EXPERTS

Find out more about the writers in this month's edition of **How It Works…**

Luis Villazon
The internet

We could think of no better expert to explain what goes on behind the scenes and inside the internet than HIW regular Luis, our resident technophile who has a degree in real-time computing.

Hannah Harris
Frogs

Her degree studies in wildlife biology made Hannah the ideal candidate to enlighten us all about one of the most popular amphibians. Find out how frogs have hopped their way through millennia.

Giles Sparrow
20 star facts

Giles studied astronomy at UCL and science communication at Imperial College, before becoming a popular science author and joining the ranks of **How It Works'** esteemed expert writers.

Tom Harris
Aluminium

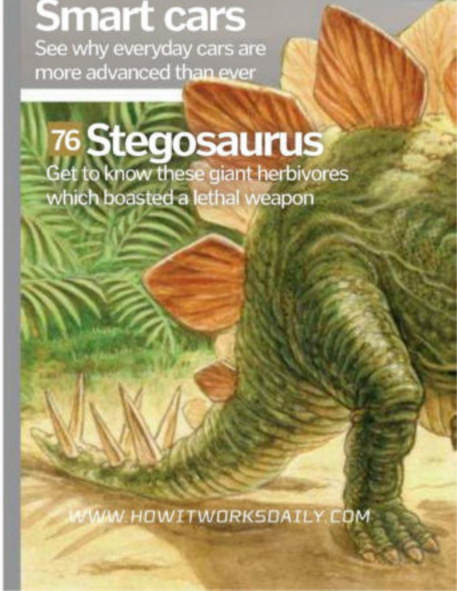
You may think you know all you need to about Earth's most abundant metal, but there's more to aluminium than meets the eye as Tom reveals how it's mined and processed as well as why it's so darn useful.

Stephen Ashby
iPhone 5

As soon as **iCreate** magazine's Stephen Ashby got his mitts on an iPhone 5 we set him to work examining the fastest, thinnest and most powerful phone Apple has ever produced from the inside out.

What's new in the iPhone 5? Go to page 64 to find out!

"When the Great Hurricane hit Barbados, bark was stripped from trees"



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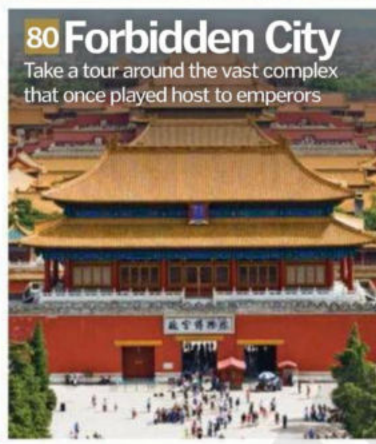
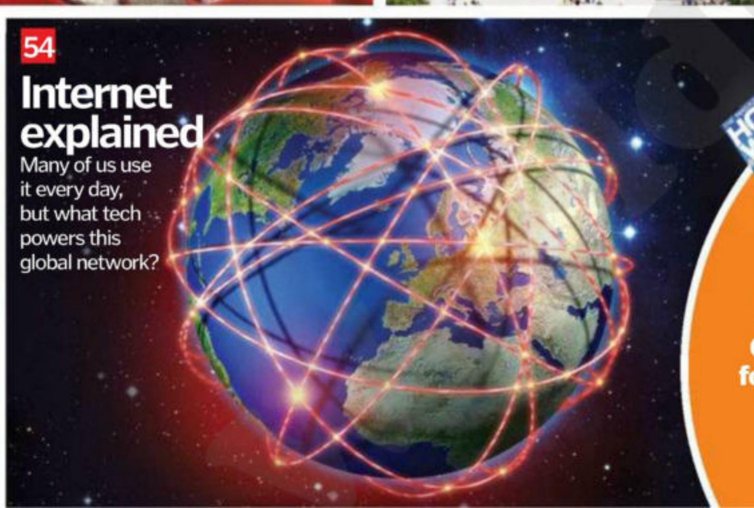




REGULARS

Skydive from edge of space

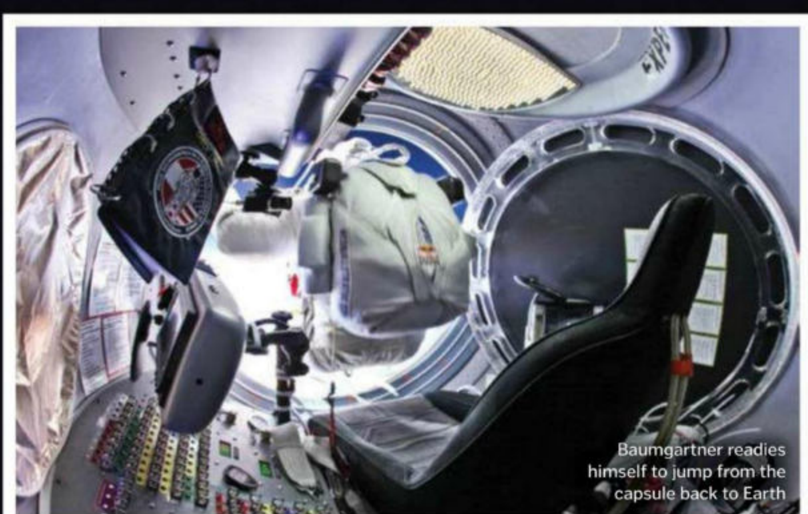
Felix Baumgartner has smashed the maximum altitude and velocity freefall descent records, jumping from 24 miles up

Austrian extreme skydiver Felix Baumgartner has broken a number of world records, including maximum altitude and maximum velocity freefall descent.

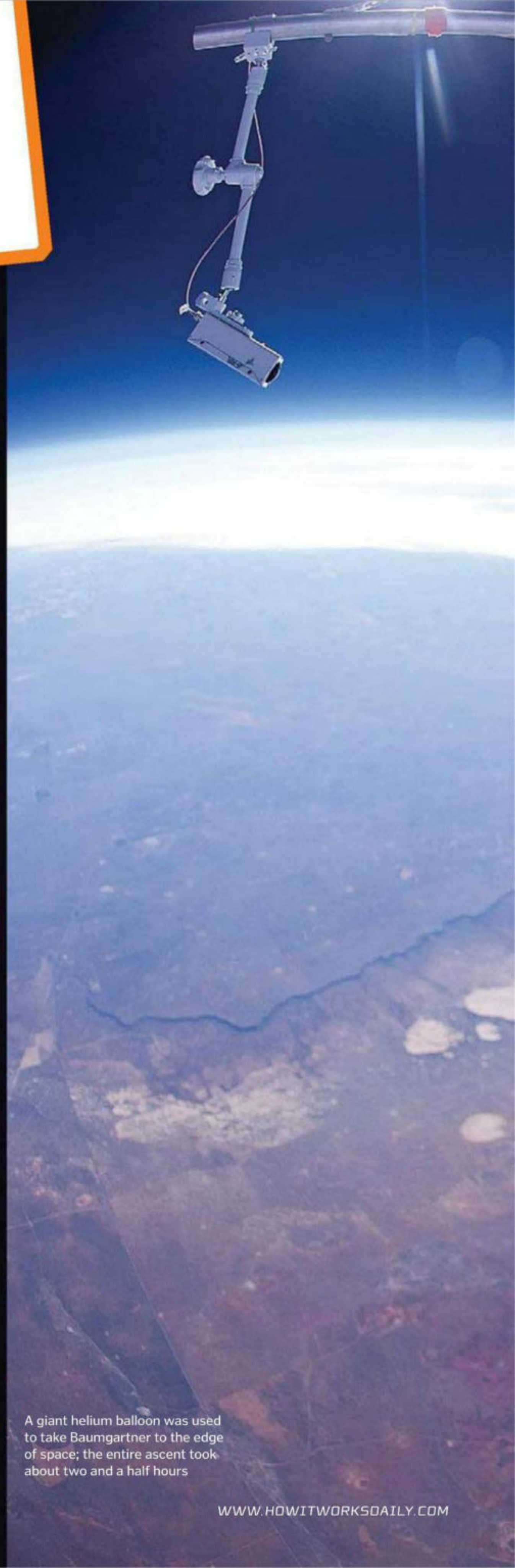
Jumping out of a specially designed space capsule that had been lifted to the edge of Earth's atmosphere by a helium balloon, Baumgartner proceeded to dive 39 kilometres (24 miles) down through the atmosphere from the edge of space, protected by a bespoke £124,000 ($200,000) dive suit.

The descent from 39,045 metres (128,100 feet), which took less than ten minutes, saw Baumgartner reach 1,342 kilometres (834 miles) per hour (breaking the sound barrier) and experience temperatures of -57 degrees Celsius (-71 degrees Fahrenheit) – factors that, along with the lack of oxygen, would have killed him almost instantly if his suit had been damaged. Luckily, Baumgartner's suit remained intact, though there were concerns that the jump may have to be aborted as there was an early fault with his visor.

With around 2,500 metres (8,200 feet) to go he opened his main parachute, before cruising down to the outlands of the famous city of Roswell, New Mexico. On landing, he officially superseded retired US Air Force Colonel Joe Kittinger as the holder of the stratospheric jump record holder, the former holding the title since his 1960 jump from 31,333 metres (102,800 feet). Kittinger has been greatly involved with Baumgartner's record attempt, acting as his crucial radio link throughout the jump.



Baumgartner readies himself to jump from the capsule back to Earth



A giant helium balloon was used to take Baumgartner to the edge of space; the entire ascent took about two and a half hours

Currently the liquid air has an efficiency rating of 70 per cent, a figure that is likely to increase as the tech matures

Is liquid air the future of fuel?

A process used to liquefy air is set to transform the way we store energy

A revolutionary process of turning air into liquid may offer a much more eco-friendly (and eventually cost-effective) solution to storing excess energy to that currently provided by existing chemical batteries.

Developed by British engineer Peter Dearman and applied by the firm Highview Power Storage, the process allows air to be chilled and condensed to a liquid state before being stored in large vessels. Once energy is needed, the liquid air can be released from storage, vaporised and heated – purely by ambient temperatures; liquid air boils at -196 degrees Celsius (-320 degrees Fahrenheit). The resultant high-pressure gaseous air can then be used to drive an expansion turbine, which in turn powers a generator, creating electricity. Crucially, this enables electricity to be fed into the National Grid at peak hours of demand, rather than, say, in the middle of the night, allowing for a huge efficiency boost. At the moment the technology is being trialled in Buckinghamshire, UK, but Highview hopes to expand its operations over the coming years if the test goes as planned.

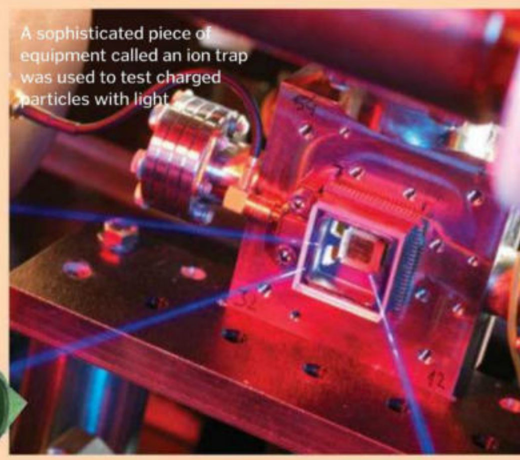

The Dragon is currently only rated to carry cargo to the ISS, however it should be cleared for human occupation by 2015

Bloodhound SSC gets all fired up

The jet car tests out its hybrid rocket system in preparation for breaking the landspeed record

The Bloodhound jet-powered car, a vehicle that is gunning to set a new landspeed record of over 1,609 kilometres (1,000 miles) per hour, has successfully fired its advanced hybrid rocket system for the first time. The hybrid rocket, which measures in at four metres (12 feet) long, 45.7 centimetres (18 inches) in diameter and weighs 450 kilograms (992 pounds), fired continuously for ten seconds and produced 6,350 kilograms-force (14,000 pounds-force) of thrust. This equates to approximately 29,839 kilowatts (40,000 horsepower).

The test fire, which was conducted inside a hardened air shelter (HAS) at Newquay Cornwall Airport, UK, had live data, video and audio streams visible in an adjacent building, where the team's engineers, as well as assembled media and guests, watched the ignition. The results, when they came in, were spectacular, and exceeded those predicted. As such, the project's chief of aerodynamics, Ron Ayers, believes that the team is now fully on course for a crack at the 1,000-mile-per-hour barrier at the Hakskeen Pan, South Africa, in 2013.


A sophisticated piece of equipment called an ion trap was used to test charged particles with light

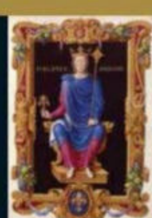
This day in history

1 November: How It Works issue 40 goes on sale, but what

365 CE
Gaul-ing attack
The Germanic Alemanni cross the Rhine and invade Gaul. Emperor Valentinian I moves to Paris to defend the Gallic cities.

996
Austria is born
Emperor Otto III refers to his land as 'Austria' for the first time in written history in a letter.

1179
King Phil
The son of Louis VII, Philip II (right), is crowned the king of France.



1512
Raising the roof
The ceiling of the Sistine Chapel (right), painted by Michelangelo, is exhibited to the public for the first time.

1604
Othello
William Shakespeare's (right) tragedy *Othello* debuts at Whitehall Palace, London.

Rise of the Dragon

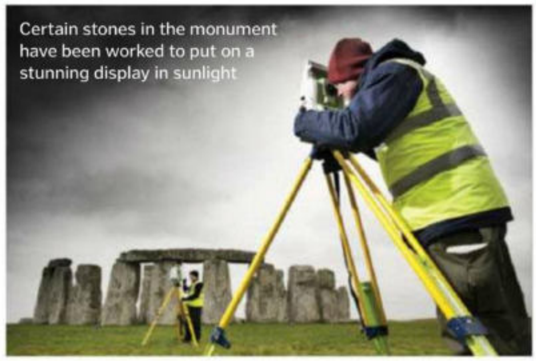
SpaceX's Dragon capsule reaches the ISS, starting a new era of commercial spaceflight

The first privately contracted re-supply mission to the International Space Station (ISS) has begun, with SpaceX's Dragon capsule successfully launching from Florida and docking with the ISS just two days later.

The mission, which is the first of 12 contracted missions from NASA, heralds the start of what is expected to be a rapidly growing private space sector. The robotic Dragon capsule – which is only cleared at the present for non-human transport – is scheduled to deliver food, clothing, experiments and spare parts to the orbiting station over a series of trips, with each one carrying 400 kilograms (881 pounds) of cargo.

Speaking on the handover of routine cargo transportation, NASA's administrator, Charles Bolden, said: "We're handing off to the private sector our transportation to the International Space Station so that NASA can focus on what we do best – exploring even deeper into our Solar System, with missions to an asteroid and Mars on the horizon."

Indeed, it is not only SpaceX which is currently eyeing future contracts from NASA, with the Orbital Sciences Corporation (OSC) – which like SpaceX is based in the States – also hoping to reach the ISS with its Cygnus capsule in the near future. In addition, both companies are looking at gaining the necessary clearance for human occupation in their respective capsules, potentially opening up the possibility of an 'astronaut taxi' sector in the coming years.



Certain stones in the monument have been worked to put on a stunning display in sunlight

Stonehenge's secret past is revealed

3D laser scanning has been used to re-create the ancient monument

According to a recent research project Stonehenge was designed so it would illuminate carved artwork on its large pillars. The project, which used 3D laser scanning technology to study the site's geometric composition and details, is basing this hypothesis on a series of 71 never-before-seen images that reveal Bronze Age carvings.

The carvings, which depict axes and arrows, were exposed by scanning the stones and creating a series of micro-topographical points on their surfaces. This produced over 850 gigabytes of model data, which later revealed carvings that are invisible to the naked eye.

The team discovered that the stones with the carvings were aligned so the Sun would illuminate them at midwinter and midsummer. Speaking on the discovery, Professor Clive Ruggles, emeritus professor of achaeoastronomy from the University of Leicester, UK, said: "This extraordinary new evidence not only confirms the importance of the solstitial alignment at Stonehenge, but how the utmost care was devoted to ensuring the pristine appearance of Stonehenge for those completing their final approach to the [site]."

Scientists scoop a Nobel prize for quantum research

US and French scientists David Wineland and Serge Haroche have been awarded the 2012 Nobel Prize in Physics. The pair were presented with the most prestigious award in science for their work on quantum optics, the analysis of single photons and charged atoms at a quantum level.

Most importantly, the scientists were chosen not just because of their experimentation, but also their creation of many of the solutions currently used to pick, manipulate and measure photons individually – something which was purely hypothetical prior to their collaboration. Professor Sir Peter Knight of the UK's Institute of Physics, commenting on the pair's award, said: "Haroche and Wineland have made tremendous advances in our understanding of quantum entanglement, with beautiful experiments to show how atomic systems can be manipulated to exhibit the most extraordinary coherence properties."

Wineland and Haroche's work is predicted to be central to the potential creation of quantum computers and light-based clocks.

else happened on this day in history?

1790

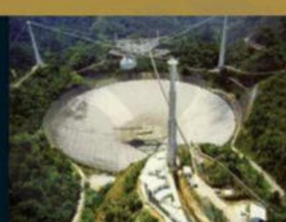
Burke's book
Irish political theorist Edmund Burke (right) publishes his book *Reflections On The Revolution In France.*

1922

Sultan quits
The last sultan of the Ottoman Empire – Mehmed VI – abdicates his throne after just four years in power.

1963

Big scope
The Arecibo Observatory (right) in Puerto Rico, the largest ever built at the time, opens.



1981

Independence
Antigua and Barbuda in the Caribbean gain their independence from the UK.

2000

Serbia
Serbia joins the United Nations at the turn of the 21st century.

10 COOL THINGS WE LEARNED THIS MONTH

AMAZING TOPICAL FACTS...

1

Solar storms disrupt satnavs

Scientists are looking into how solar storms can disrupt satellite navigation across the world after a study showed they can reduce satnav accuracy by several metres. Bursts of electromagnetic radiation that accompany solar storms are already known to affect electronic systems, but the effect of this radiation on the ionosphere and passing GPS signals is less well understood.

2

Some fish look like humans

This is Naso brevirostris, known as the spotted unicorn among other names. Its prominent nose is actually a horn that biologists suspect it uses as a means of courtship, although it does make the fish look uncannily human in profile. That's not the unicorn fish's biggest talent though: it can also change colour to suit its mood (eg it turns dark grey when stressed).

3

A 'MacGyver' robot is under development

The Georgia Institute of Technology has received a $900,000 (£562,000) US Navy grant to make a 'MacGyver' bot. "Our goal is to develop a robot that behaves like MacGyver," said professor Mike Stilman, referring to the Eighties TV character. The aim is to create a robot capable of using any tools in its environment to accomplish its task.

©GIT

4

The oceans are becoming acidic

A study by NOAA has pointed to increasingly acidic oceans, where carbon dioxide released by decaying algae blooms in nutrient-rich areas is lowering pH levels. This particularly affects the growth of corals and shellfish.

5

Honey can be blue

Bees in the Ribeauvillé region of France confused apiarists recently by making blue and green-coloured honey. The mystery was solved when it was discovered that the bees were eating the sugary waste from M&Ms, found in a plant that dealt with waste from a Mars factory. The operator has since solved the problem, as the beekeepers have declared the honey unsaleable.

6

The UK's biggest spider has returned

The great raft spider, a species with a leg span of up to eight centimetres (3.2 inches) that fishes in wetlands, is set to return after teetering on the brink of extinction. Scientists have bred the rare arachnid in test tubes and have started translocating hundreds of them to their native East Anglian wetlands.

7

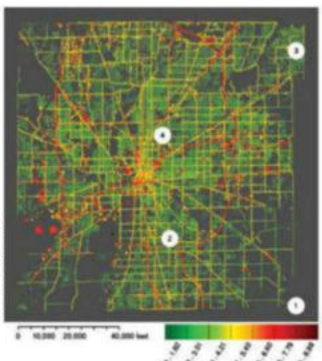
The Sun rises in different places throughout the year

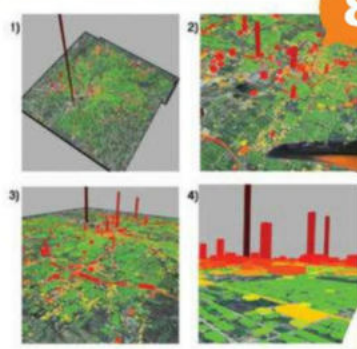
Amateur photographer Tunc Tezel took this superb composition image of a sunrise analemma. This is the figure-of-eight swoop that results from snapping the Sun at the same time of day in the same location over a number of months. In this case, the 17 images were taken at 0231 UT between 2 April and 16 September 2012 in Baku, Azerbaijan. There's something extra in a Sun near the top too: the tiny black dot was the transit of Venus on 6 June.

© Tunc Tezel

Cities can be carbon-mapped

New software has been developed by University of Arizona researchers that maps carbon emissions across an entire city right down to individual buildings. It's called the Hestia Project, after the Greek goddess of the hearth and home, and it uses public databases, traffic simulations and energy consumption models to create a map that grades low to high carbon emissions in colours of green through to red, respectively.



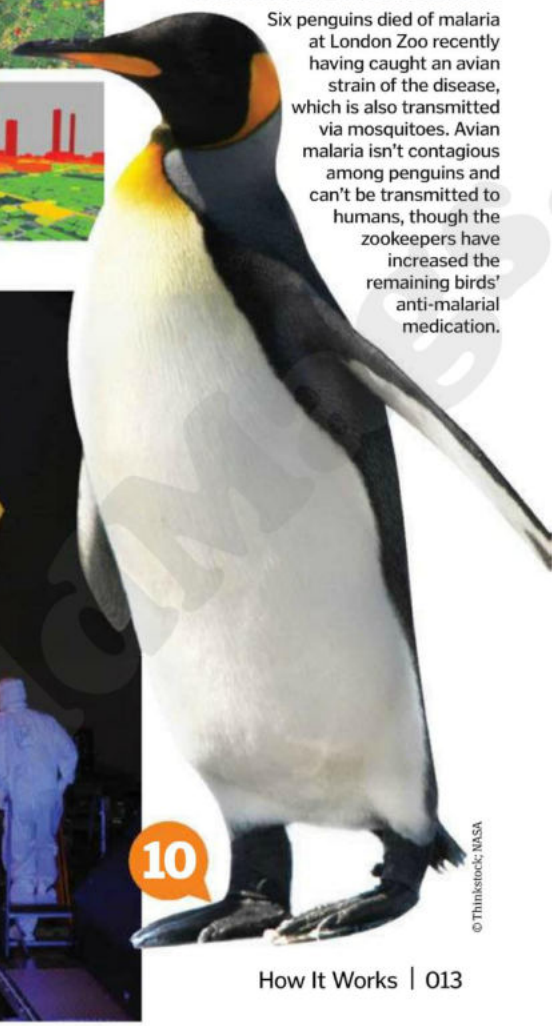


© Hestia Project ASU

8

Penguins can catch malaria

Six penguins died of malaria at London Zoo recently having caught an avian strain of the disease, which is also transmitted via mosquitoes. Avian malaria isn't contagious among penguins and can't be transmitted to humans, though the zookeepers have increased the remaining birds' anti-malarial medication.



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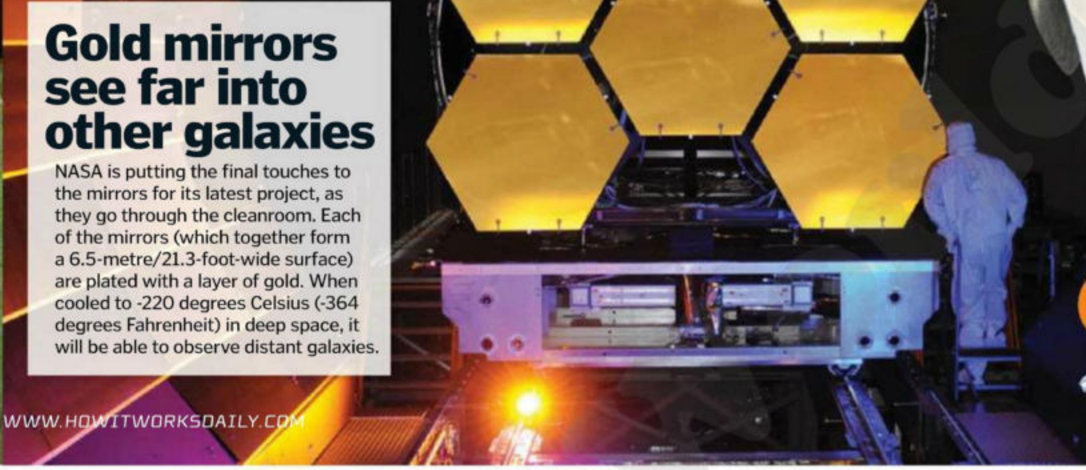


9

Gold mirrors see far into other galaxies

NASA is putting the final touches to the mirrors for its latest project, as they go through the cleanroom. Each of the mirrors (which together form a 6.5-metre/21.3-foot-wide surface) are plated with a layer of gold. When cooled to -220 degrees Celsius (-364 degrees Fahrenheit) in deep space, it will be able to observe distant galaxies.

© Thinkstock; NASA

EXTREME WEATHER

Uncovering the origins of the most savage meteorological phenomena that the world has ever seen

'A butterfly flaps its wings in China and a hurricane hits Florida' – or at least so goes the well-known saying. That's usually a metaphorical expression that describes the Butterfly Effect, the idea that the sequence of events which leads to an eventual outcome is so chaotic and so far removed from its source that it's near impossible to determine. In the case of predicting the weather, however, it can be taken literally. Though meteorologists might not be quite at the stage of pinning a specific weather pattern down to the movements of an insect, they have got the science of weather prediction down to a fine art. But they do get it wrong sometimes.

In mid-October 1987, UK meteorologists predicted a spot of bad weather would hit the south coast of Britain but the deepening depression over the continent would progress no farther than the English Channel. As it turned out, the depression not only moved on to the UK mainland, but also plummeted to a low of 953 millibars at the centre of what would later be christened the 'Great Storm of 1987'. Indeed, it was the worst tempest to hit northern Europe in nearly 300 years, with winds gusting up to 196 kilometres (122 miles) per hour in the UK and even faster in France. It downed around 15 million trees, caused nearly £5 billion ($8 billion) worth of damage and forced the National Grid to shut down the power supply to London.

As a force 11/12 storm on the Beaufort scale at worst, the Great Storm of 1987 would be the equivalent of a category 1 hurricane or a severe tropical storm. It's weather that subequatorial regions are well used to, if not prepared for, but which is unheard of in more temperate climes. The fortunate thing about these freak occurrences is that, more often than not, they can be traced to a source. So even if we can't do anything to stop it happening again, scientists are more informed of the signs of extreme weather and perhaps we can be more prepared the next time a mega-storm hits.

In this eight-page feature, we delve into some of the most extreme examples of weather from across the globe, what makes them so weird, the meteorological records they broke, the damage they caused, as well as the human cost. Where did the freak storms come from? What conditions gave rise to those temperatures and will anyone ever see rain like that again? **HIW** traces the floods, droughts, winds, rains and more back to their source to find out exactly what took them to a whole other level.

"The Phoenix haboob included heavy metal pollutants, fungi and bacteria that could cause eye infections"

The Phoenix haboob

Where: Phoenix, USA **When:** 18 August 2011
Fatalities: 3 **Weather type:** Dust storm

What you see here isn't a cloud or smoke from a fire , but a haboob: a dust storm of monumental proportions that hit Phoenix, Arizona, in August 2011. Although the dust storms themselves aren't especially unusual in the region, this was a monster at two kilometres (1.2 miles) high and 100 kilometres (62 miles) across.

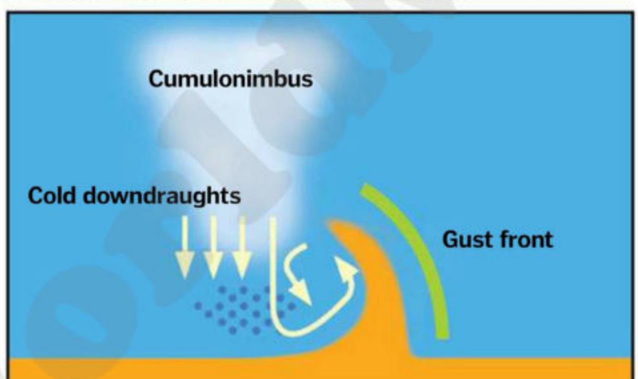
Early June marks the beginning of the monsoon season for Arizona and it's where this massive haboob began its life. Most of the land was still very dry when a large thunderstorm-forming depression settled over the desert, causing winds to move into its centre. When it collapsed, the winds reversed and downdraughts of up to 100 kilometres (62 miles) per hour blew across the arid region, kicking up a huge wall of dust that swept over the city.

Haboobs occur in several desert areas, including the Middle East and Australia. They're not particularly dangerous, but the dust gets everywhere and they can leave a covering of up to 0.3 metres (one foot) of sand. The Phoenix haboob included additional hazards in the form of heavy metal pollutants, fungi and bacteria that could cause eye infections and lung diseases.

Sudan sees a lot of haboobs – in fact, it is where the name originates

Cool fact

They may just be dust, but haboobs can take down power lines, jam electrical devices and play havoc with aircraft.



© Getty

Australian fire devil

Where: Alice Springs, Australia **When:** 16 September 2012
Fatalities: 0 **Weather type:** Fire devil

They're more akin to dust devils than tornadoes, but the flaming columns that form fire devils are much rarer than either. They're hardly ever seen and rarely last long, which makes this most recent event in the Australian outback so much more incredible.

Filmmaker Chris Tangey had been working in the Alice Springs area when he was confronted with this 30-metre (100-foot) pillar of flame. Not only did it 'sound like a fighter jet', but it lasted nearly 40 minutes, giving Tangey ample time to video it and take photographs.

Fire devils can occur when a column of warm air forcing its way up either comes in contact with a fire or conditions are right for it to create a spark. In the case of this fire devil, a bush fire that had raged for a week, plus an extended dry spell since April 2012, along with a perfectly still day were ripe conditions for the fire tornado.

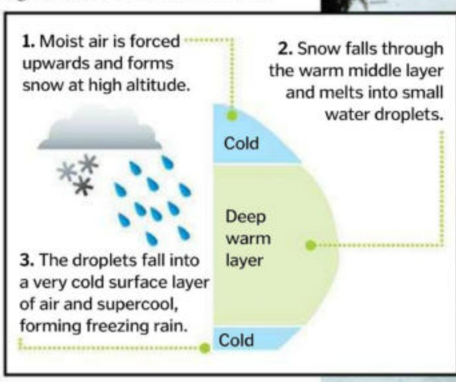
Cool fact
Fire devils have been seen reaching as high as 1km (0.6mi) into the air.

The North American Ice Storm of 1998

Where: North-east America **When:** 7 January 1998 **Fatalities:** 55
Weather type: Ice storm **Damage:** $6 billion (£3.7 billion)

Ice storms are common on the east coast of the US and Canada. The infrastructure is generally prepared for the havoc these storms can wreak, but winter 1998 brought with it the most crippling ice storm in living memory.

By 5 January 1998 it was clear eastern North America was in for a cold spell. An area of unusually high pressure was sitting over the Atlantic, trapping several weather systems on the land. Arctic air was being held at the surface in this area, while a front of low pressure was feeding it with warm, moist air from the Gulf of Mexico. The result was 12.7 centimetres (five inches) of freezing rain that fell over 80 hours, crystallising on anything it touched, taking down power lines, felling trees and making roads impassable everywhere. One of the worst-hit cities was Montréal in Québec.



> "Over the bitter winter of 1683-1684, the River Thames in London totally froze over for two months"

The Tri-State Tornado

Where: Southern USA **When:** 18 March 1925 **Fatalities:** 695 (confirmed)
Weather type: F5 tornado **Damage:** $16.5m ($1.4bn/£873m today)

The deadliest tornado in US history was part of a tornado outbreak that struck the southern states in spring 1925. It touched down in Missouri and tracked north-east through Illinois and on to Indiana where it dissipated. In its wake the F5 monster – the highest possible rating on the Fujita scale – destroyed 15,000 homes and killed hundreds of people. It could move at 110 kilometres (70 miles) per hour, travelled 352 kilometres (219 miles) and, because it was so massive, it appeared as an enormous black, ground-hugging cloud, rather than the characteristic funnel shape.

The Tri-State Tornado was born out of a cold low-pressure system that had been following what we now know is the jet stream, down from Canada, along the Texas-Oklahoma border and into Missouri. It's here that it hit a warm front from the Gulf of Mexico and conditions were made perfect for a tornado outbreak. Judging by the speed the Tri-State Tornado travelled at, it's likely the winds in the jet stream were particularly strong at the time.

The Little Ice Age

Where: Northern Europe **When:** 1350-1850
Damage: N/A **Weather type:** Global cooling

The 'Little Ice Age' wasn't a true ice age, but a period of significant cooling that took place worldwide (though it was felt most keenly in northern Europe) over the course of 500 years. It was punctuated by several brief warming periods with the coldest period manifesting itself in the late-17th and early-18th centuries. It's during the winters over this period that the European landscape completely changed to something evocative of what might happen if a real ice age occurred. Over the bitter winter of 1683-1684, the River Thames in London completely froze over for two months and in Switzerland entire villages were lost to advancing glaciers.

Evidence suggests that this period of global cooling could have been caused by a number of factors combined. Volcanic activity around Indonesia in the 13th century had a likely long-term effect, while a very slight shift in the Earth's orbit at this time definitely contributed. The dips in this cooling period also coincided with minimums in solar activity.

1931 Yellow River flood

Where: China **When:** July-November 1931 **Fatalities:** Up to 4 million
Weather type: Flood **Damage:** Unknown billions

In 1931, China experienced one of the deadliest natural disasters ever. Having had a two-year drought, China's three big rivers burst their banks over three months: the overflowing Yangtze and Huai drowned nearly half a million people between them, but casualty estimates of the Yellow River flood are as high as 2 million. Millions more faced starvation and sickness from waterborne diseases like cholera. Both the human and financial costs are hard to calculate. No single factor can be blamed for this tragic event, but it's believed that large amounts of meltwater from a particularly snowy winter, combined with heavy spring rain, began the abnormal flooding season. This was followed by no less than seven torrential typhoons in July alone, when China usually only sees two in a whole year.

These days, Yellow River flood relief comes in the form of a controlled burst from the Xiaolangdi Dam

Cool fact

The Yellow River has several dams, which have been broken in the past to use the river as a weapon against enemy armies.

FEATURE

I-44 Tornado Corridor

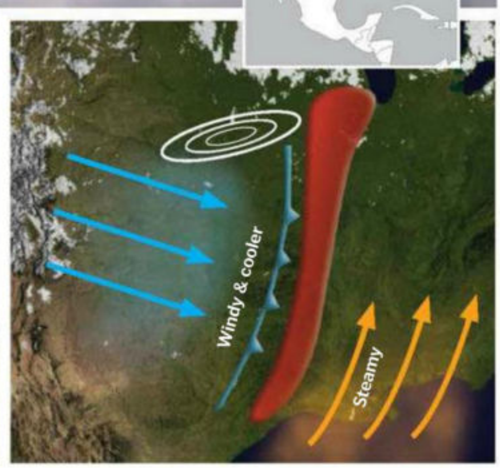
Where: Oklahoma, USA **Weather type:** Tornadoes

There are several regions of the world where tornadoes have a tendency to touch down on a regular basis, but the 177-kilometre (110-mile) strip of land that runs from Oklahoma City to Tulsa is one of the most notorious. It follows part of the St Louis to Wichita Falls Interstate 44 (hence the name) and has seen hundreds of destructive tornadoes tear down its length in the last century. The worst of these have ploughed a strip straight through Oklahoma City itself and, on 3 May 1999, no less than 70 touched down in the region. One of these was a devastating F5 on the Fujita scale that killed 40 people, left thousands homeless and caused $1 billion (£620 million) of damage.

Conditions at spring time make the I-44 corridor ripe for tornadoes: as warm, moist air drifts north from the Gulf of Mexico across the southern states, it's met by cool, dry air moving high off the tops of the Rocky Mountains to the west. Combined with the huge, flat expanses of land in the region, it's perfect for twisters.

Cool fact

Tornadoes can (and have) formed in the UK, though the great plains of America are the perfect breeding ground for them.

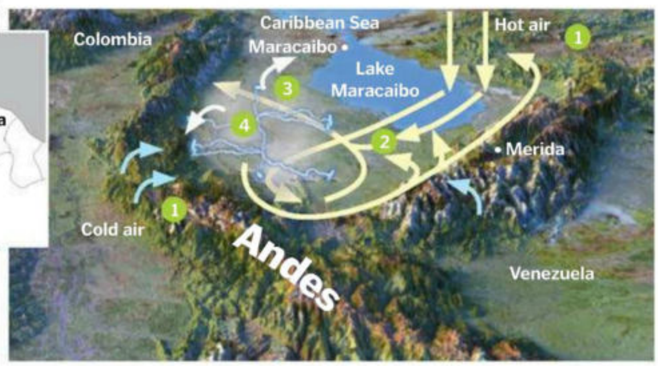


Lighthouse of Maracaibo

Where: Lake Maracaibo, Venezuela
Weather type: Lightning

There's a lightning storm over Lake Maracaibo that has raged on and off for centuries. This unique phenomenon can be seen from many miles away, illuminating the lake and its surroundings for up to 160 nights a year. Recent data from the University of Zulia showed the Maracaibo Lake basin to have the hottest flash density rate in the world, with an annual average of 181 lightning flashes per square kilometre. Indeed, during peak months, there can be 50 discharges every minute!

The Lighthouse of Maracaibo is caused by very specific conditions. The wind that blows in across the plains is trapped by the surrounding Andes and Perijá mountains, along with the warm, moist air it collected from the plains. The swampy land in this region produces a lot of methane, which rises into the charged clouds and is the catalyst for near-continuous lightning.



1. Warm, damp air originating from the Caribbean is cooled by the cold Andes mountains, creating stormy conditions.
2. Decomposing matter in the swamps below creates lots of methane, which rises into the clouds.
3. Circulating currents of air distribute the methane but it concentrates in pockets.
4. The air in the cloud normally insulates lightning, but the methane weakens this insulation, allowing the electricity to discharge.

Cool fact
Continental drift opened Drake Passage 41 million years ago, creating the Antarctic Circumpolar Current which helps to keep the continent cold.

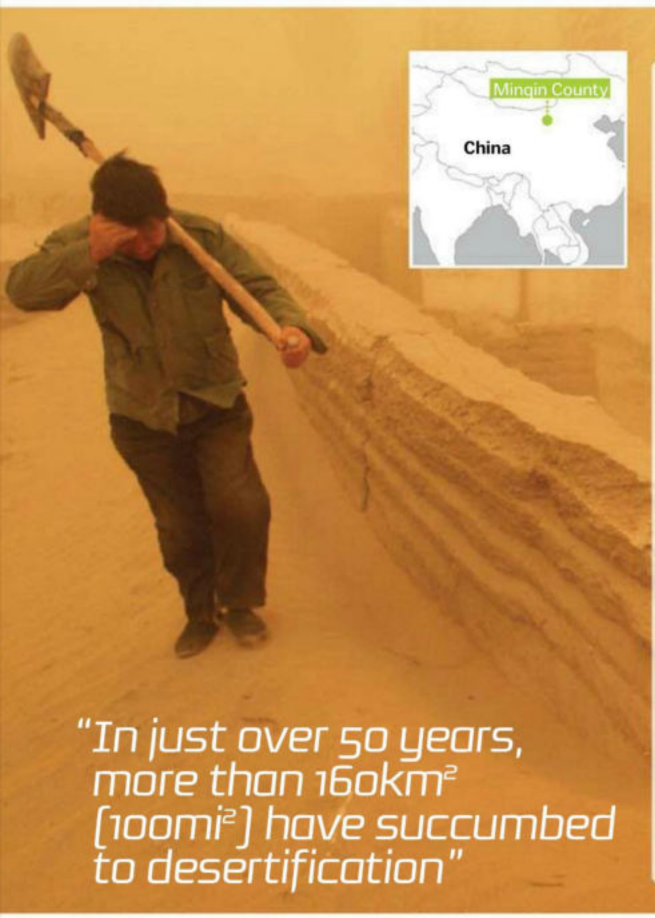
The storms of Drake Passage

Where: South Atlantic/Pacific
Weather type: Sea storm

It's known as the roughest patch of ocean in the world ever since English privateer and explorer Sir Francis Drake gave it his name in 1578. Drake Passage is a stretch of water 800 kilometres (500 miles) wide from the southern tip of South America to the frosty islands that surround Antarctica.

These seas are rarely anything less than choppy and are frequently diabolically rough, challenging even the most seasoned navigators and sailors. The wind in alternate passages from the southern Atlantic into the Southern or Pacific Oceans is often too strong to make any headway against, so Drake Passage is usually chosen as the lesser of two evils despite its treacherous waters.

The Antarctic Circumpolar Current that travels swiftly through Drake Passage is made rough by the high winds that move from west to east at this latitude, creating waves that are frequently ten metres (32 feet) or higher.



"In just over 50 years, more than 160km² (100mi²) have succumbed to desertification"

The Creeping Sandbox

Where: Gansu province, China
Weather type: Sand storm

To most of us, a desert is an arid region that is relatively fixed. We don't think of them as growing entities that can overwhelm communities in our lifetime, but that's exactly what's happening to the once fertile Minqin Oasis region of China.

This farming community is being rapidly evicted by two deserts that sandwich it: the Tengger to the south-east and Badain Jaran to the north-west. In just over 50 years, more than 160 square kilometres (100 square miles) have succumbed to desertification by the sands that advance at ten metres (32 feet) a year. While arable land has decreased from 580 to 100 square kilometres (360 to 60 square miles), the population has more than doubled, so farmers constantly need to relocate. Part of the reason Minqin is being swallowed up so fast is a long-term drought in the area and because the oasis's life source – the Shiyang River – has been diverted farther upstream.

Airborne invaders

Australian Dust Storm

2009 saw a dust storm of enormous proportions engulf the Australian territories of New South Wales and Queensland. It was highly concentrated and was nearly 3,500 kilometres (2,175 miles) long at its peak. Meteorologists suspect that a low-pressure front and 100-kilometre (62-mile)-per-hour winds picked up dust from the dry interior and carried it to the coast.

Réunion Island rains

The island of Réunion, east of Madagascar, boasts seven of the world's top ten rainfall records, including: 182.4 centimetres (71.8 inches) in 24 hours and 5.7 metres (18.63 feet) in ten days. It sits in the path of cyclone rainclouds, which have to move up the steep mountains of the island, resulting in a staggering amount of rain.

Meschera money storm

In the summer of 1940, a shower of 1,000 or so 16th-century silver coins reportedly dropped on the Meschera region of Russia during a violent storm. It's suspected that the coins were from a buried treasure hoard that was ripped out of the ground, perhaps by a falling tree, and carried up by high winds before being dropped.

1972 Iran Blizzard

Freezing temperatures and storms in southern Iran resulted in up to eight metres (26 feet) of snow blanketing more exposed areas, killing 4,000 people and burying several villages entirely.

Cyclones, typhoons and hurricanes

Devastating wind storms come with many names, but do they differ in any way?

What's the difference between a cyclone, a typhoon and a hurricane? In fact, there is none. These are the regional names given to a certain type of violent storm. So, cyclones occur in the south Pacific and Indian Ocean, typhoons in the north-west Pacific, while in the Atlantic or north-east Pacific they're called hurricanes.

These violent storms are characterised by extremely strong winds that can gust in excess of 200 kilometres (125 miles) per hour, torrential rain, floods and extremely high seas. At the centre of these storms is an 'eye', a circular region typically between 30 and 65 kilometres (20 and 40 miles) wide that moves with the storm and marks the low point of the atmospheric depression. The eye itself is cold, deceptively calm and sunny, though the strongest winds and thunderstorms encircle its border, forming the eyewall.

The ingredients for a storm of this type include an existing weather system combined with warm seas, which is why they only ever occur in subequatorial latitudes. These storms don't form within 500 kilometres (300 miles) of the equator because they rely on the swirling Coriolis effect for its rotation, which diminishes to zero the closer you are to the equator. With rare exceptions, neither do they form in waters with a surface temperature colder than around 26 degrees Celsius (80 degrees Fahrenheit), which rules out much of the rest of the world.

As with many types of extreme weather, the size and intensity don't necessarily reflect its notoriety: the typhoon, for example, is typically several times bigger than its Atlantic cousin, the hurricane. But many smaller hurricanes have achieved a higher profile simply because they made landfall and devastated the highly populated southern states of the US.

Key

Cyclones, hurricanes and typhoons form in the warm waters near the equator from where they circulate away. Their general course is predictable, though it's hard to know what they will do or how strong they will get over longer periods.

Hurricanes

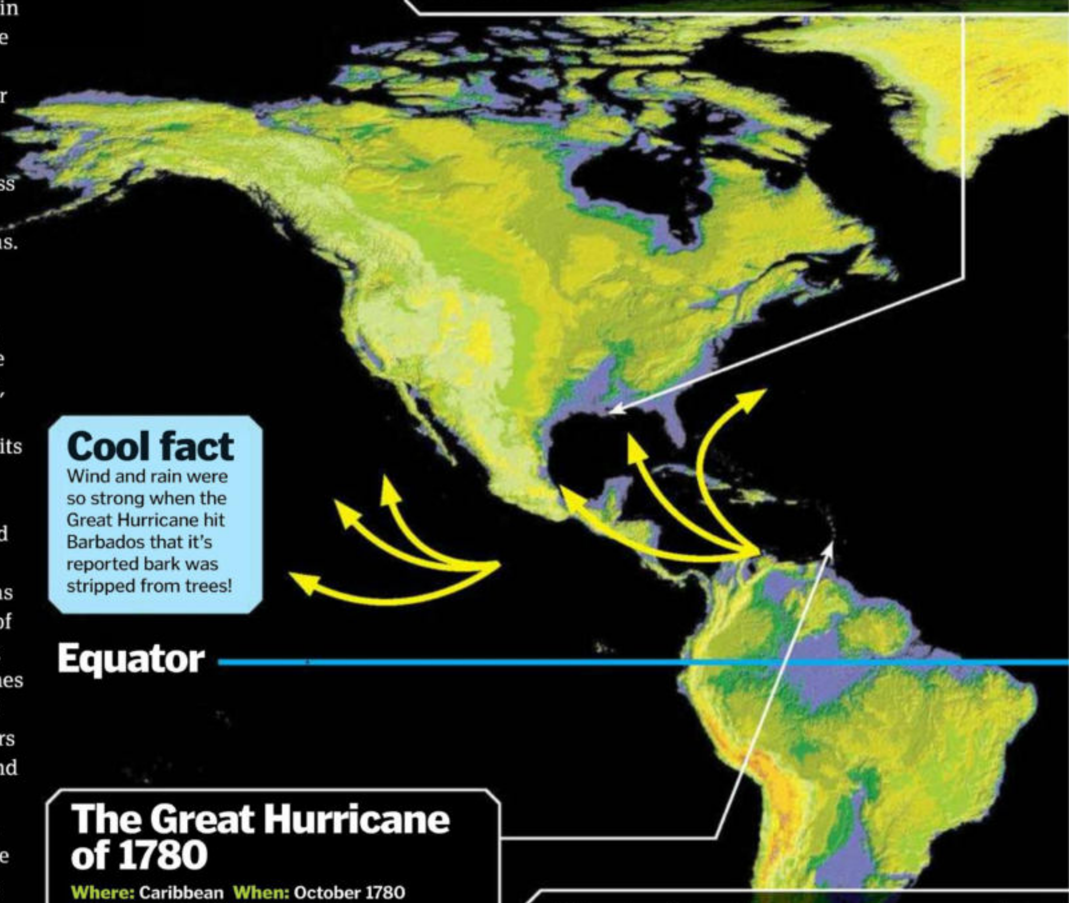
Cyclones

Typhoons

Hurricane Katrina

Where: New Orleans, USA **When:** August 2005
Fatalities: 1,833 **Damage:** $108bn (£670m)

One of the deadliest hurricanes in recent memory and the most destructive in US history, Hurricane Katrina profoundly affected New Orleans and its surroundings, where water reached up to 20 kilometres (12 miles) from the shore. Hurricane Katrina was the child of a waning tropical depression and an atmospheric trough known as a tropical wave. It moved across the Gulf of Mexico and rapidly strengthened over unseasonably warm waters, transforming into a maximum-rated category 5 hurricane and shifting away from Florida shortly before it slammed into the vulnerable city of New Orleans in south-east Louisiana.



Cool fact

Wind and rain were so strong when the Great Hurricane hit Barbados that it's reported bark was stripped from trees!

The Great Hurricane of 1780

Where: Caribbean **When:** October 1780
Fatalities: 22,000 **Damage:** Unknown

Simply known in English as the Great Hurricane of 1780, this category 5 beast is the deadliest hurricane on record. It predates when records officially began in 1851, so there's no exact data. It's likely though that its wind speed exceeded 320 kilometres (200 miles) per hour and it devastated the relatively unprepared parts of the Antilles in the Caribbean Sea. Casualties include fleets of British and French ships that were vying for control of the region as a part of the American Revolution. It's likely it formed in the eastern part of the Atlantic Ocean picking up strength as it approached Barbados.

Bhola Cyclone

Where: Bangladesh **When:** November 1970
Fatalities: 500,000 **Damage:** $490m (£306m)

The Bhola Cyclone was, meteorologically speaking, far from record-breaking. Its winds of around 140 kilometres (87 miles) per hour made it the equivalent of a relatively modest category 3 or 4 hurricane. But it struck a very vulnerable low-lying area of eastern Pakistan with a six-metre (20-foot) storm surge at night. With no way of warning locals, the authorities were helpless as hundreds of thousands drowned. Bhola formed from the remnants of a tropical storm and another depression in the Bay of Bengal, intensifying over four days and sweeping north into what is now Bangladesh.

Hurricane Vince

Where: Portugal/Spain **When:** October 2005
Fatalities: 0 **Damage:** N/A

Its winds peaked at 120 kilometres (75 miles) per hour, which only just registers as an official hurricane, it caused no damage and there were no fatalities, so why could Hurricane Vince be considered 'extreme'? Because of its unheard-of Spanish location and because of conditions at the time, which should never have produced a hurricane. The reasons for its formation near Madeira still aren't understood. The 22-degree-Celsius (72-degree-Fahrenheit) seas should never have allowed the 25-kilometre (15-mile) eye to form within the tropical storm. But form it did, and it lasted several hours, breaking up just before it hit the Spanish mainland.

Cool fact

Hurricane Vince proved to be a blessing in disguise, dropping several inches of rain on a drought-ridden Spain.

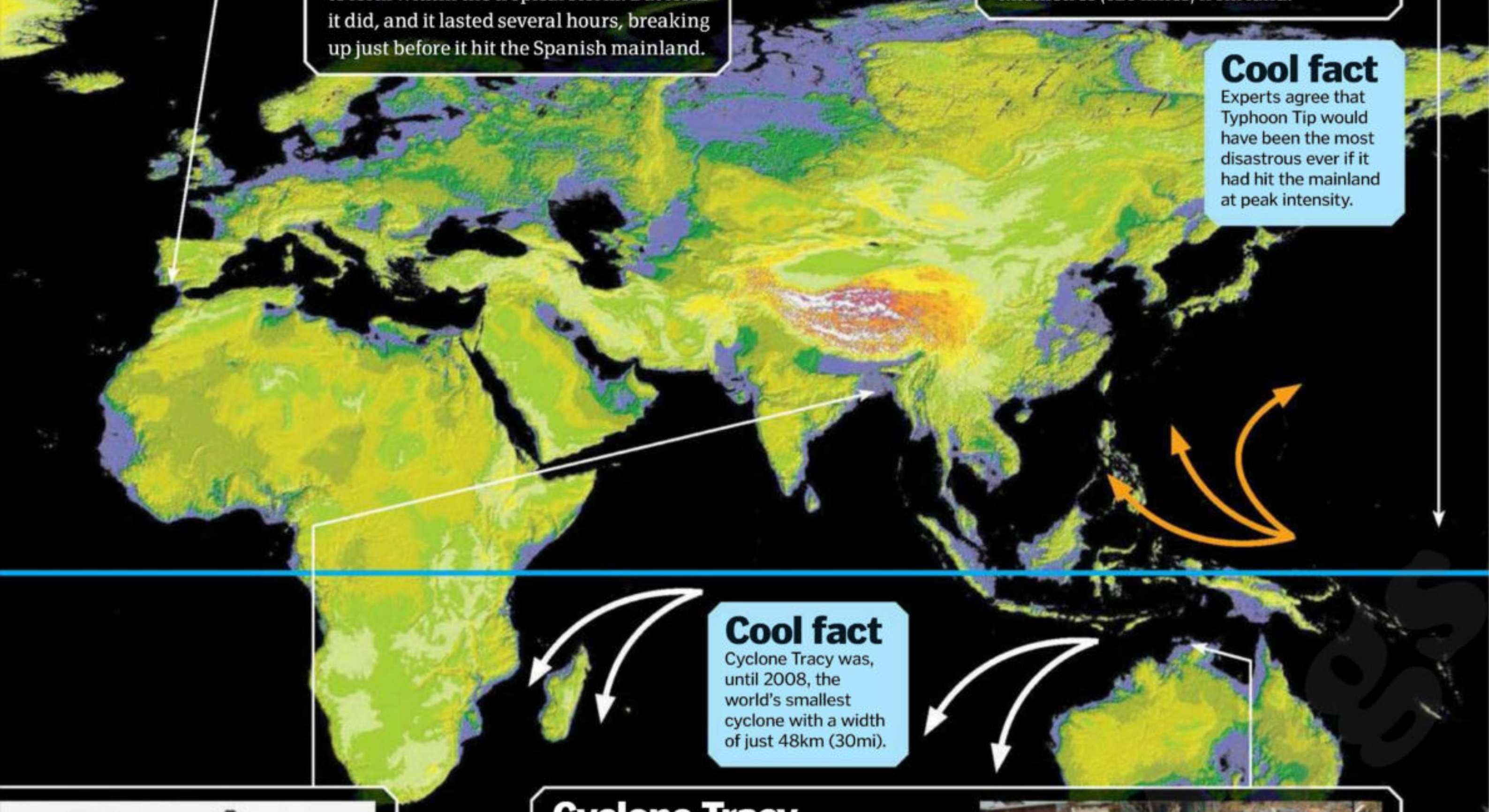
Super Typhoon Tip

Where: Eastern Pacific **When:** October 1979
Fatalities: 86 **Damage:** Unknown

Super Typhoon Tip was a monster, even for a typhoon. It broke several records: it had a diameter of 2,220 kilometres (1,380 miles) – nearly twice that of the previous record holder. It had sustained winds of 260 kilometres (160 miles) per hour and also set the world record for intensity with a staggering pressure low of 870 millibars. Typhoon Tip originated south of Micronesia though it remained a tropical storm until it made a sudden westerly diversion from Guam, where it intensified considerably and hit its peak nearly 1,000 kilometres (620 miles) from land.

Cool fact

Experts agree that Typhoon Tip would have been the most disastrous ever if it had hit the mainland at peak intensity.



Cool fact

Cyclone Tracy was, until 2008, the world's smallest cyclone with a width of just 48km (30mi).

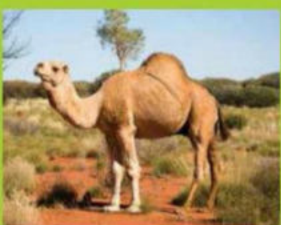
Cyclone Tracy

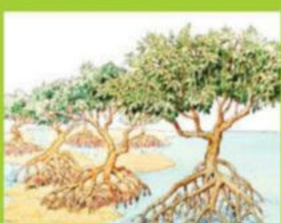
Where: Darwin, Australia **When:** 25 December 1974 **Fatalities:** 71 **Damage:** $586m (£366m)

On Christmas Day 1974, a category 4 cyclone swept through Darwin, Australia, with winds gusting in excess of 217 kilometres (135 miles) per hour towing a four-metre (13-foot) storm surge. Locals had been warned, but partly due to the season and partly because Cyclone Selma had failed to make landfall earlier that month, many made no preparations at all. Cyclone Tracy developed in the seas 500 kilometres (300 miles) north of Australia and spent the next few days tracking south-east until it hit the warm water of the Timor Sea, where it intensified dramatically.

categories explained
Animals | Climate | Geography | Geology | Plants | General

This month we turn the spotlight on one of the most popular amphibians. Find out how frogs develop from tadpoles, why some can kill humans and how they differ from toads. We also reveal why kangaroos are born to jump, how the oldest lake formed and the ecosystems mangrove forests support.





LEARN MORE

The life of frogs

Kissing one won't produce a prince, but there's plenty to love about frogs just the way they are

All frogs and toads are amphibians and members of the order Anura, which means tailless. Although they are most plentiful in the tropics, frogs are found in all continents except Antarctica.

A frog's skin is permeable, allowing the frog to absorb both water and oxygen. This means these creatures can breathe even underwater for long periods. Species that must survive long periods of extreme cold use glucose produced by the liver as a type of antifreeze, which protects their organs from damage, even if the water in and around the frog turns to ice! Frogs are largely carnivorous, eating mostly insects. They hunt by sight, but they see better far away than close up and they don't perceive still objects well. However, they make up for this in their ability to detect moving prey, which many species can pluck out of the air with retractable sticky tongues. Their eye position means frogs can sit almost entirely submerged while still able to watch for potential food or predators.

When it comes to romance, the frog relies on sound rather than sight to find a mate. Males use enlarged mouths or throat pouches to amplify their call over long distances. Though not famous for their family life, some frogs demonstrate elaborate parental skills. Indeed, a few species in places without much accessible water raise their babies in specialised pouches in their skin or even in their mouths for the entire tadpole phase, before releasing them.

How frogs develop

See how a common frog undergoes an amazing transformation from egg to adult in around 16 weeks

Week 1
Frogspawn
When frog eggs are laid, the tiny embryo is enveloped in layers of protective jelly.

1-2
Larva
As the larva develops, it releases hormones which cause the egg to split apart.

2
Hatchling
With few exceptions, tadpoles are fully aquatic, using their strong tails to propel them around in search of food.

1. NOT POISONOUS

Common frog
The most populous species of frog in the UK. Their skin can vary from olive-green to brown and features dark blotches. They are in no way toxic.

2. QUITE POISONOUS

Dyeing dart frog
The third largest of its species can reach five centimetres (two inches) long, yet it's far less lethal than some of its relatives.

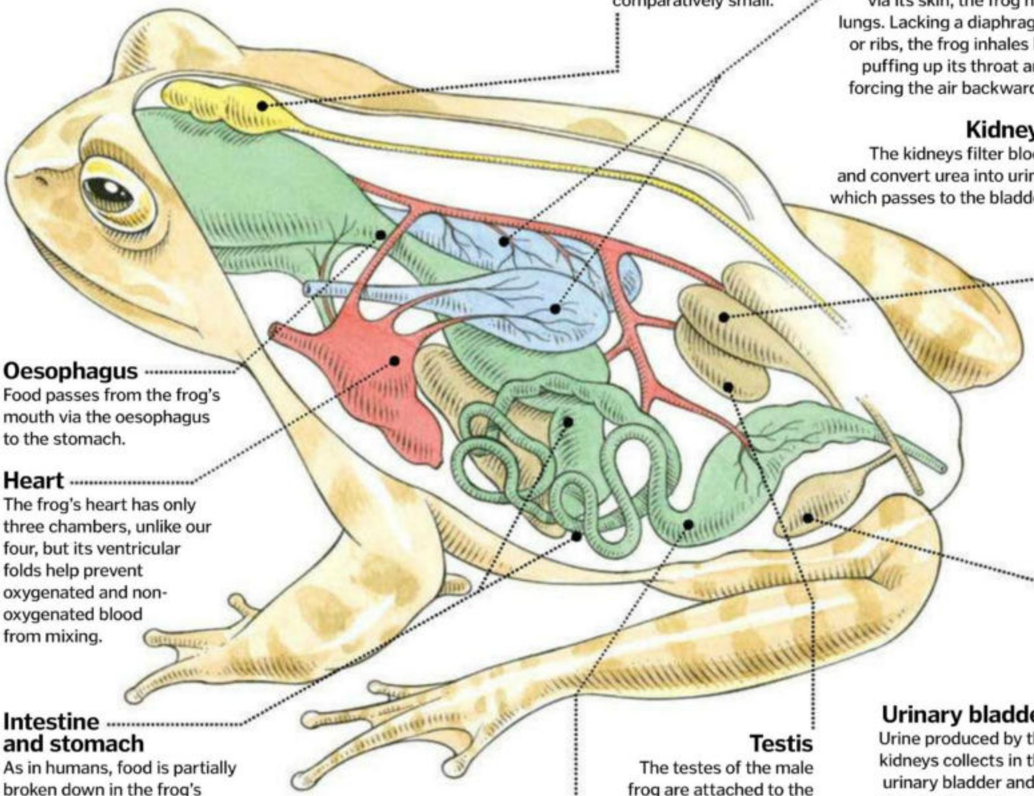
3. SUPER POISONOUS

Golden poison frog
Each of these innocent-looking frogs carries enough poison to kill 20,000 mice. However it's used only in defence.

DID YOU KNOW? Red-eyed tree frogs use startle coloration to ward off predators, flashing their brightly coloured body parts

What's inside a frog?

Often used to teach anatomy, frogs have a body plan much like our own – but with a few important differences...



Brain
A frog's brain has the same main components ours do, but the cerebellum is comparatively small.

Lungs
In addition to breathing via its skin, the frog has lungs. Lacking a diaphragm or ribs, the frog inhales by puffing up its throat and forcing the air backwards.

Kidneys
The kidneys filter blood and convert urea into urine, which passes to the bladder.

Oesophagus
Food passes from the frog's mouth via the oesophagus to the stomach.

Heart
The frog's heart has only three chambers, unlike our four, but its ventricular folds help prevent oxygenated and non-oxygenated blood from mixing.

Intestine and stomach
As in humans, food is partially broken down in the frog's stomach before passing into the intestine where most of the digestion takes place.

Cloaca
Both liquid and solid waste, as well as sperm and eggs, all wind up in the cloaca, where they are ejected from the body via the cloacal vent.

Testis
The testes of the male frog are attached to the kidneys. Male frogs lack a penis, so sperm is ejected directly onto the eggs as they are laid by the female.

Urinary bladder
Urine produced by the kidneys collects in the urinary bladder and is periodically discharged into the cloaca.

The statistics...

Frog

Type: Amphibian

Order: Anura

Diet: Usually carnivorous, though often herbivorous at the tadpole stage of development

Average life span in the wild: Estimated at 4-15 years

Size: From 7.7mm (0.3in) up to 33cm (12.9in)

Distribution: Global, except Antarctica

Poison dart frogs

Bright, beautiful and potentially lethal, members of the Dendrobatidae family, aka poison dart frogs, let would-be predators know they should dine elsewhere. Their colourful skin exudes alkaloid compounds that make some of these tiny frogs among the most deadly vertebrates alive. However, they can't do it alone: poison dart frogs actually obtain their toxicity from their arthropod prey, eg mites. This means frogs born and raised in captivity are non-toxic, because they can't synthesise these compounds independently. The most toxic frogs produce batrachotoxins and less potent pumiliotoxins, both of which are cardiotoxins, causing muscle spasm, arrhythmia and death.

Spot the difference

Frog

Habitat: Frogs require a moist environment to live and many are fully aquatic.
Skin: Usually smooth and appears wet or slimy.
Body shape: Relatively long, slim bodies with pointy snouts and long hind legs.
Locomotion: Webbed feet, which they use to execute long jumps and to swim.
Head: Large protuberant eyes, and often a row of small cartilaginous teeth.
Eggs: Usually lay their eggs in a large gelatinous mass.
Defences: Main defence for most frogs is to hide or flee. S some species are highly toxic.

Toad

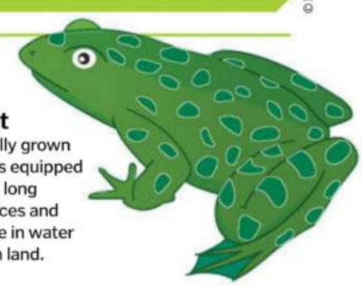
Habitat: Can withstand drier conditions so can spend more time on land.
Skin: Bumpy or warty-looking and also dryer.
Body shape: Chubby with a blunt snout and short limbs.
Locomotion: They walk or take short hops.
Head: Defined brow ridges but the eyes are not as bulgy. Toads have no teeth.
Eggs: Typically lay eggs in long strands but a few species give birth to live young.
Defences: A large parotid gland behind each eye which can secrete poison, as can their skin to a lesser extent.

3-10
Larval tadpole
Most frogs are carnivorous, but many tadpoles are herbivorous. They use spiral tooth ridges to scrape algae off rocks.

10-12
Froglet
Legs emerge from under the gill sac; the gut shortens; eyes shift and change; plus ear structures and skin glands develop.

12-16
Teen frog
The tail is the last vestige of tadpole life to disappear. The frog is nearly fully developed.

16
Adult
The fully grown adult is equipped to hop long distances and survive in water and on land.



"Capable of an 8m [25ft] single bound, the red kangaroo is one of the world's greatest long jumpers"

Why camels have the hump

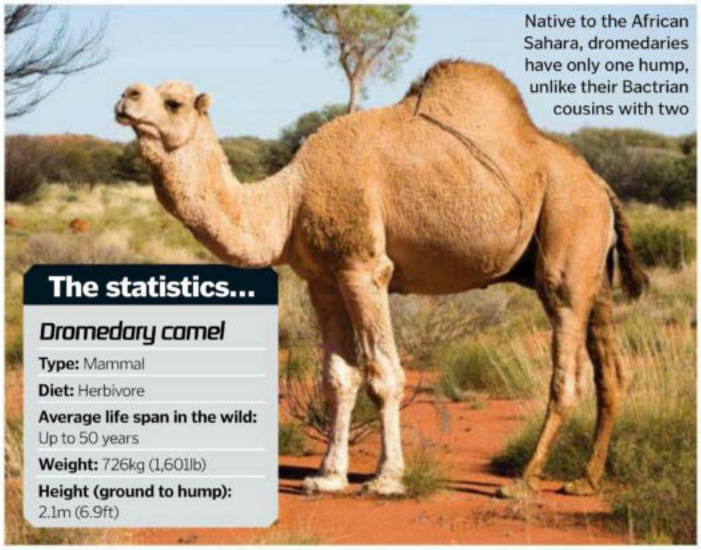
How do these 'ships of the desert' adapt to life in extreme climates?

Camels are experts at living where food and water are scarce. The reason they can survive in such arid terrain is their amazing ability to conserve the water they do take on. When a dehydrated camel finds a water source, it can lap up as much as 120 litres (32 gallons) in 15 minutes. To conserve the lifesaving H_2O, camels can regulate their body temperature so that they hardly sweat at all. Their kidneys can concentrate the urine to further reduce water loss.

Not only this but these creatures also store a lot of water in their blood; the erythrocytes (red blood cells) can swell to over twice their normal size without bursting. Thanks to this tailored physiology, camels can go for weeks with little to no food or water.

However, when sustenance is in seriously short supply, they make use of a secret energy stash on their backs. The camel's hump does not store water; it functions as a reserve of adipose tissue (fat cells) that can metabolise to provide emergency energy. As the fat is depleted, the hump will begin to wilt and flop to one side.

These fatty humps are great for keeping cool too as fat conducts the Sun's heat relatively slowly, and their woolly covering provides extra insulation.



Native to the African Sahara, dromedaries have only one hump, unlike their Bactrian cousins with two

The statistics...

Dromedary camel

Type:	Mammal
Diet:	Herbivore
Average life span in the wild:	Up to 50 years
Weight:	726kg (1,601lb)
Height (ground to hump):	2.1m (6.9ft)

Why are kangaroos expert jumpers?

Discover why this antipodean animal is a natural-born long jumper

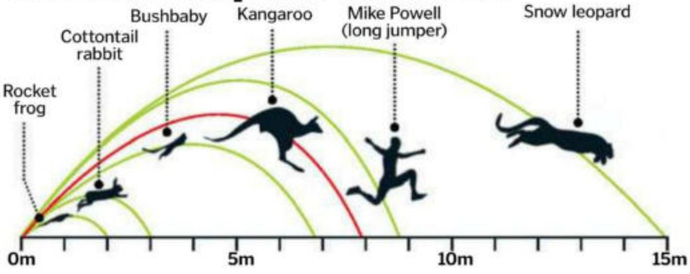
In a huge country such as Australia, the ability to cross vast distances in search of food and water is key to survival. And one such animal that can traverse barren lands at high speed for hours is the kangaroo.

Capable of an eight-metre (25-foot) single bound across level ground, the red kangaroo is one of the world's greatest long jumpers. Thanks to large feet and strong legs, it can also travel at over 50 kilometres (30 miles) per hour. While a kangaroo's hind legs are big and powerful, they can't work independently of each other and so kangaroos have to hop on two feet.

The hind leg tendons are strong and elastic and, with every hop, elastic energy is recaptured in the tendons ready for the next jump.

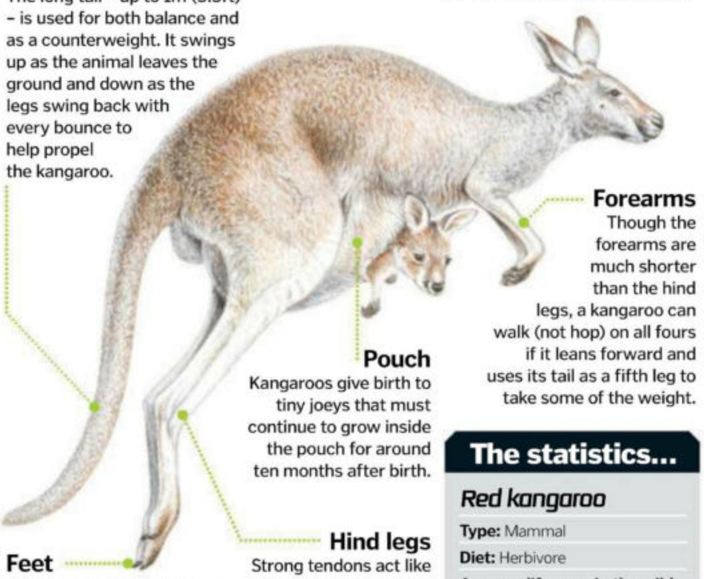
To help the bounce, kangaroos use their tails as a counterbalance. It propels the animal in a similar way to using your legs on a swing to gain momentum. When the kangaroo's back legs are fully outstretched behind it the tail is in the downward position, and when the legs are pushing forwards the tail is high in the air.

Who can leap the farthest?



Built to bounce

Why is this Australian marsupial so good at the long jump?



Tail
The long tail – up to 1m (3.3ft) – is used for both balance and as a counterweight. It swings up as the animal leaves the ground and down as the legs swing back with every bounce to help propel the kangaroo.

Forearms
Though the forearms are much shorter than the hind legs, a kangaroo can walk (not hop) on all fours if it leans forward and uses its tail as a fifth leg to take some of the weight.

Pouch
Kangaroos give birth to tiny joeys that must continue to grow inside the pouch for around ten months after birth.

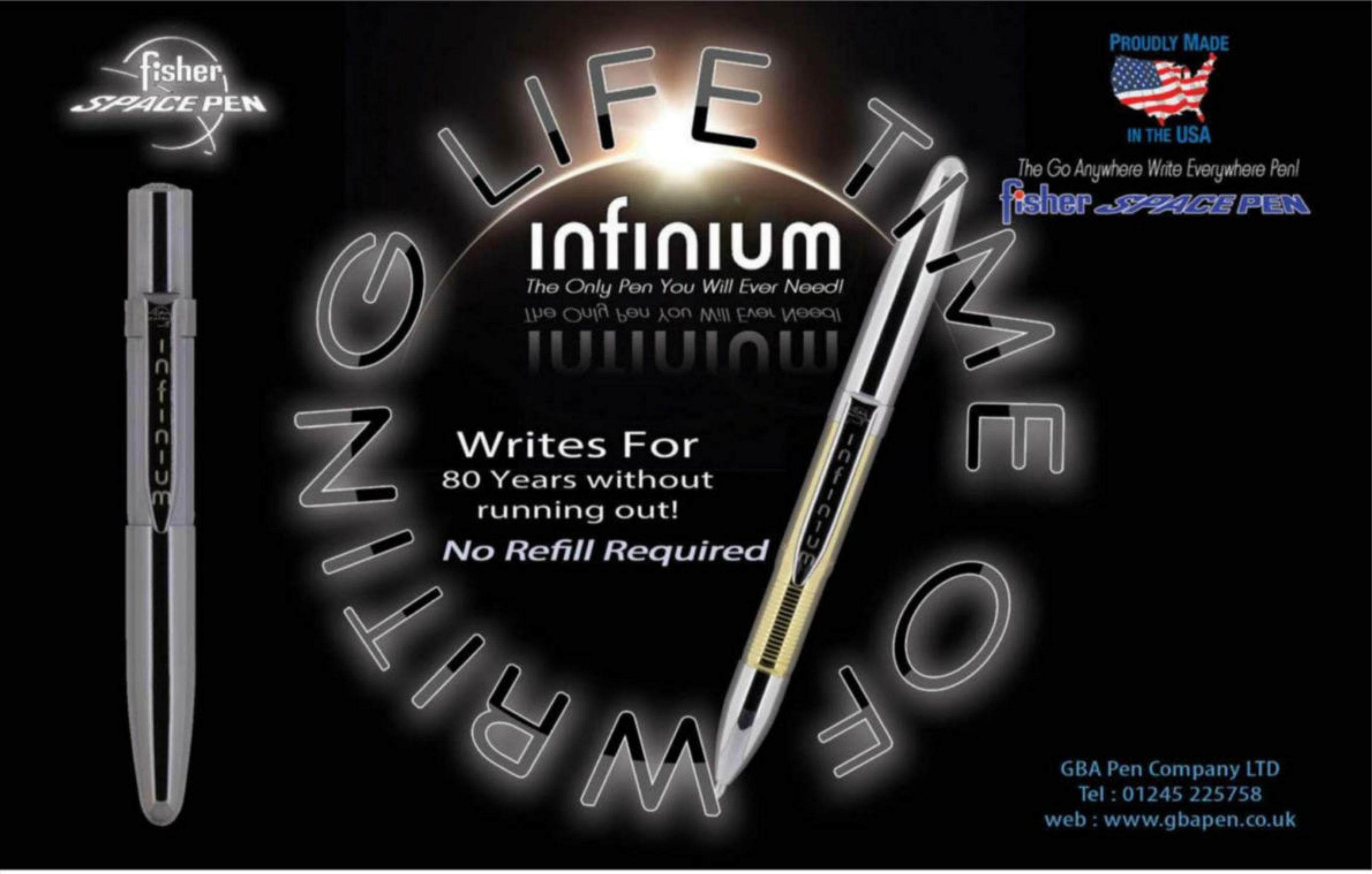
Feet
A kangaroo's big toes are in the centre of the other toes (not to one side like ours) in line with their leg bones, which enables them to push off with force.

Hind legs
Strong tendons act like tightly wound springs that store and release energy. On touching down, the spring is compressed, storing energy for the next hop.

The statistics...

Red kangaroo

Type:	Mammal
Diet:	Herbivore
Average life span in the wild:	20 years
Weight:	90kg (200lb)
Size:	1-1.6m (3.3-5.3ft)
Speed:	56km/h (35mph)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"Today Lake Baikal contains an astonishing 20 per cent of the world's unfrozen fresh water"

The world's deepest lake

How did Lake Baikal form and what makes it so important to science?

In a southern region of Siberia near the border of Mongolia is Lake Baikal, not just the most ancient lake in the world at 25 million years old, but the deepest too. To be precise it is 1,642 metres (5,387 feet) at its deepest point, which is deep enough to stand five Eiffel Towers (each 324 metres/1,063 feet) on top of one another and for the top-most tower to still not break the surface.

Because of its great age, we can't be certain of how Lake Baikal formed, unlike many inland seas and lakes that can usually be attributed to the movement of glaciers during previous ice ages. However, it's suspected that the body of water was originally a river bed during the Palaeogene epoch. Over millions of years it formed several shallower and narrower lakes that were connected by rivers during the Pliocene epoch, before the lakes gradually joined to become one – still in the Pliocene, while plate movement created the deep basin.

Today Lake Baikal contains an astonishing 20 per cent of the world's unfrozen fresh water, which is still very pure despite pollution from a coastal paper mill and where the Selenga River feeds into the lake.

It's also one of the most biodiverse lakes on the planet with 1,340 species of animal and 570 species of plant – nearly half of which are endemic to the lake ecology. Coupled with its natural beauty, this is why Baikal was made a UNESCO World Heritage Site in 1996.

Baikal's underwater neutrino telescope

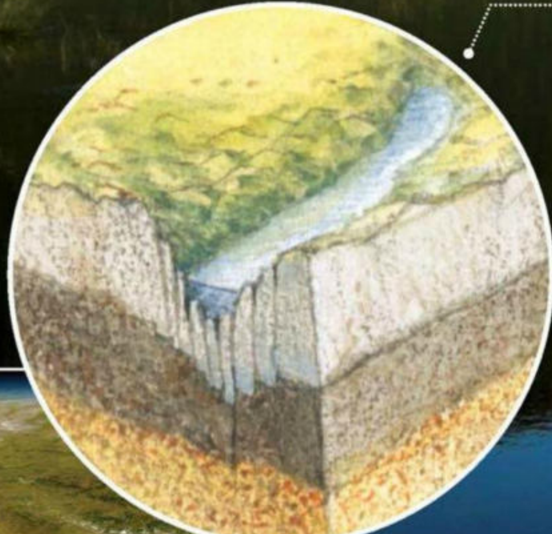
Floating near the bottom of Lake Baikal is a telescope called the NT-200. It's not looking at stars and galaxies, and neither is it studying the strange life on the lake bed. NT-200 is actually pointing towards the Earth's core and trying to find a neutrino: a particle with no charge that only has a very weak interaction with matter, so it can pass straight through any material, including the Earth, without hitting anything.

Russian scientists are trying to find the elusive high-energy neutrino released by gamma-ray bursts and their ilk, but there's too much noise created by relatively common low-energy neutrinos caused when cosmic rays hit the Earth's atmosphere. To screen most of them out, the 42 x 70-metre (140 x 230-foot) NT-200 telescope has been placed a kilometre (0.6 miles) down in the depths of Lake Baikal.

Ancient depths

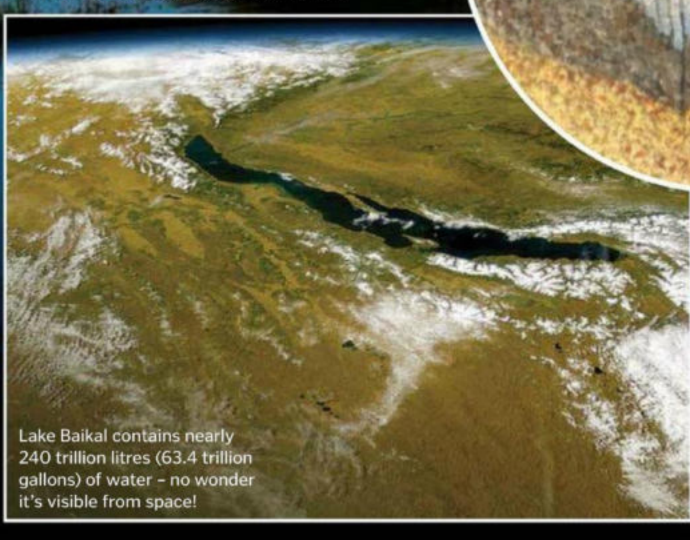
Though the present bottom of Lake Baikal is nearly 1,700 metres (5,600 feet) down, the depth of the fissure it sits in is deeper. Much deeper in fact: it's estimated that to reach the bedrock at the deepest part you'd have to dig through around eight kilometres (five miles) of sediment, making the Lake Baikal trench nearly as far down as the Mariana Trench (ie 11 kilometres/6.8 miles) – the deepest oceanic trench in the world.

The sediments have collected over millions of years, the oldest of which at the base of the trench began stacking up when South America and North America were yet to form a land bridge and the Earth's climate was considerably warmer.



How Lake Baikal measures up

Incredibly, the bottom of the deepest part of the rift Lake Baikal sits in is nearly 8,000m (26,247ft) below the base of the lake bed.



Lake Baikal contains nearly 240 trillion litres (63.4 trillion gallons) of water – no wonder it's visible from space!

What is the crab-eating macaque's staple diet?

A Fruit, seeds and plants B Crabs C Pizza

Answer:
Crab-eating macaques are found all over South-East Asia, but particularly in mangroves. Strangely, despite their name, they seldom eat crabs. They're opportunistic omnivores and 90 per cent of their diet is actually fruit, seeds and plants.

DID YOU KNOW? The Sundarbans in Bangladesh is the largest mangrove forest on Earth covering 140,000 hectares

What are mangroves?

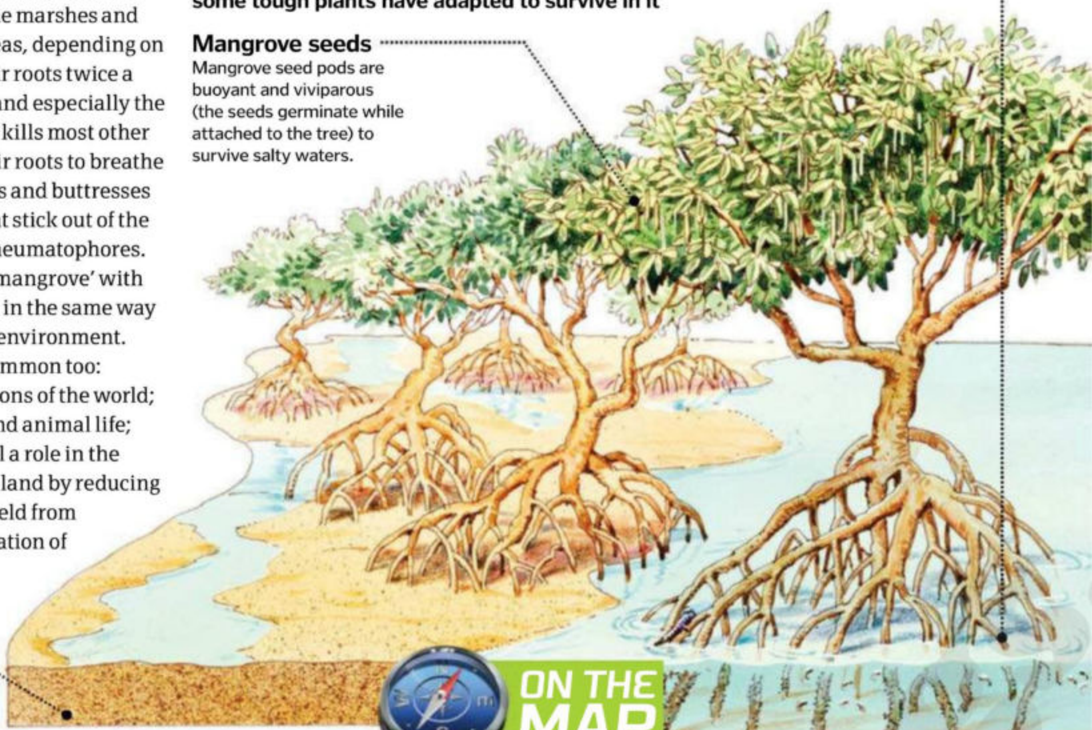
How does this coastal woodland develop and can it really be as important as rainforest?

A mangrove is a highly adapted type of tree of which there are around 70 known species from several families of plants that include palms and holly trees. They're highly adapted to saline marshes and swamps along the coast or in estuarine areas, depending on very soft soils and tides that wash over their roots twice a day. Most species are resistant to the heat and especially the extreme salinity of their environment that kills most other plants. All have adaptations that allow their roots to breathe in waterlogged soil, either by the prop roots and buttresses mangrove trees are famous for, or roots that stick out of the mud and take in air like snorkels, called pneumatophores.

Most people tend to associate the word 'mangrove' with the ecosystem a mangrove forest provides, in the same way the word 'rainforest' broadly describes its environment. Rainforests and mangroves have a lot in common too: they're both found in many equatorial regions of the world; they support an enormous array of plant and animal life; and the forests themselves play just as vital a role in the region around them. They help to stabilise land by reducing sediment washing out to sea, provide a shield from tsunamis and prevent saltwater contamination of inland bodies of water like aquifers.

The mangrove ecosystem

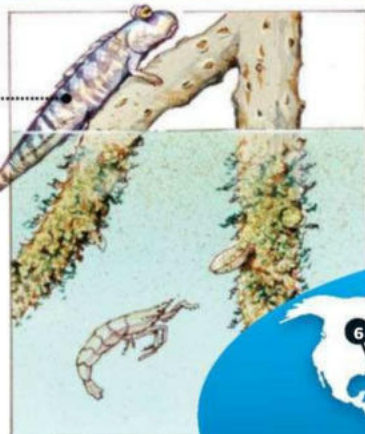
Take a closer look at this unique habitat and how some tough plants have adapted to survive in it



Prop roots
The loose soil of marshes doesn't make for very solid foundations, but a complex weave of roots keeps these mangrove trunks upright.

Mangrove seeds
Mangrove seed pods are buoyant and viviparous (the seeds germinate while attached to the tree) to survive salty waters.

Soil
Mangrove forests prevent soil erosion and also can create new land. Over 1,200km² (465mi²) were gained in Bangladesh by planting mangroves.



Mangrove wildlife
Mangrove inhabitants include shrimp and these mudskippers, but they're also home to endangered species like the manatee.

Salty waters

Saltwater can be poisonous to plant life. Too much salt results in plant tissue salt saturation that interferes with metabolic processes and swiftly causes death. So how do mangroves survive? Mangrove plants exhibit one of two main adaptations to deal with excess salt. Some are ultrafiltrators and can selectively absorb specific ions in water, leaving behind up to 97 per cent of the sodium at the roots. The remainder of the salt is removed through transpiration. Another method is to secrete salt in a concentrated solution through special glands, which crystallises on the surface of the plant and is removed by wind or rain.

ON THE MAP

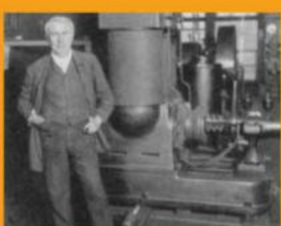
Mangrove forests around the world

1 India
2 Australia
3 Bangladesh
4 Madagascar
5 Brazil
6 Florida

From the home to our vehicles and our favourite gadgets, aluminium is everywhere, but what properties make this metal so versatile? Also learn about the lightest material on Earth, how our bodies stay at 37°C (98.6°F) and the evolution of the electric light bulb.

33 **Slinky science**

36 **Bee stings**



38 **Electric light bulbs**

LEARN MORE

Aluminium

It's the most abundant metal in the Earth's crust, yet it entirely escaped our notice until 1825

You might say it was hidden in plain sight. Aluminium is a highly reactive metal, meaning it readily undergoes chemical reactions with other elements and compounds to form different substances. As a result, nearly all of the naturally occurring aluminium atoms on Earth ended up tucked away in the molecules of more than 270 different minerals, including gemstones like emeralds and rubies. So, while it's actually 8.2 per cent of the Earth's crust, making it the most common metal and third-most common element (behind oxygen and silicon), you would never know it's there without investigating on the chemical level.

The statistics...

Aluminium

Protons: 13
Neutrons: 14
Electrons: 13
Melting point: 660.3°C (1,220.5°F)
Boiling point: 2,467°C (4,472.6°F)
Superconduction temperature: -271.975°C (-457.5°F)
Density of solid: 2,700kg m^{-3}
Atomic weight: 26.981539 atomic mass units
Reflectivity: 71%
Atomic radius: 118 picometres

The search was on in the mid-1700s, when chemists began experimenting with alum, a class of abundant chemical compounds. Alum compounds, such as potassium aluminium sulphate, were well known, going back at least to the Ancient Greeks and Romans, who used them as an astringent to close wounds and a mordant to bind dye to cloth. Early chemical investigation of alum suggested that the compound included an unknown metal.

The trouble was that 18th-century chemists had no way to separate the mystery element from the rest of the atoms in the compound. In 1825, the Danish chemist Hans Christian Ørsted finally devised a chemical

RECORD BREAKERS
CANNY COLOSSUS

8,460LTRS

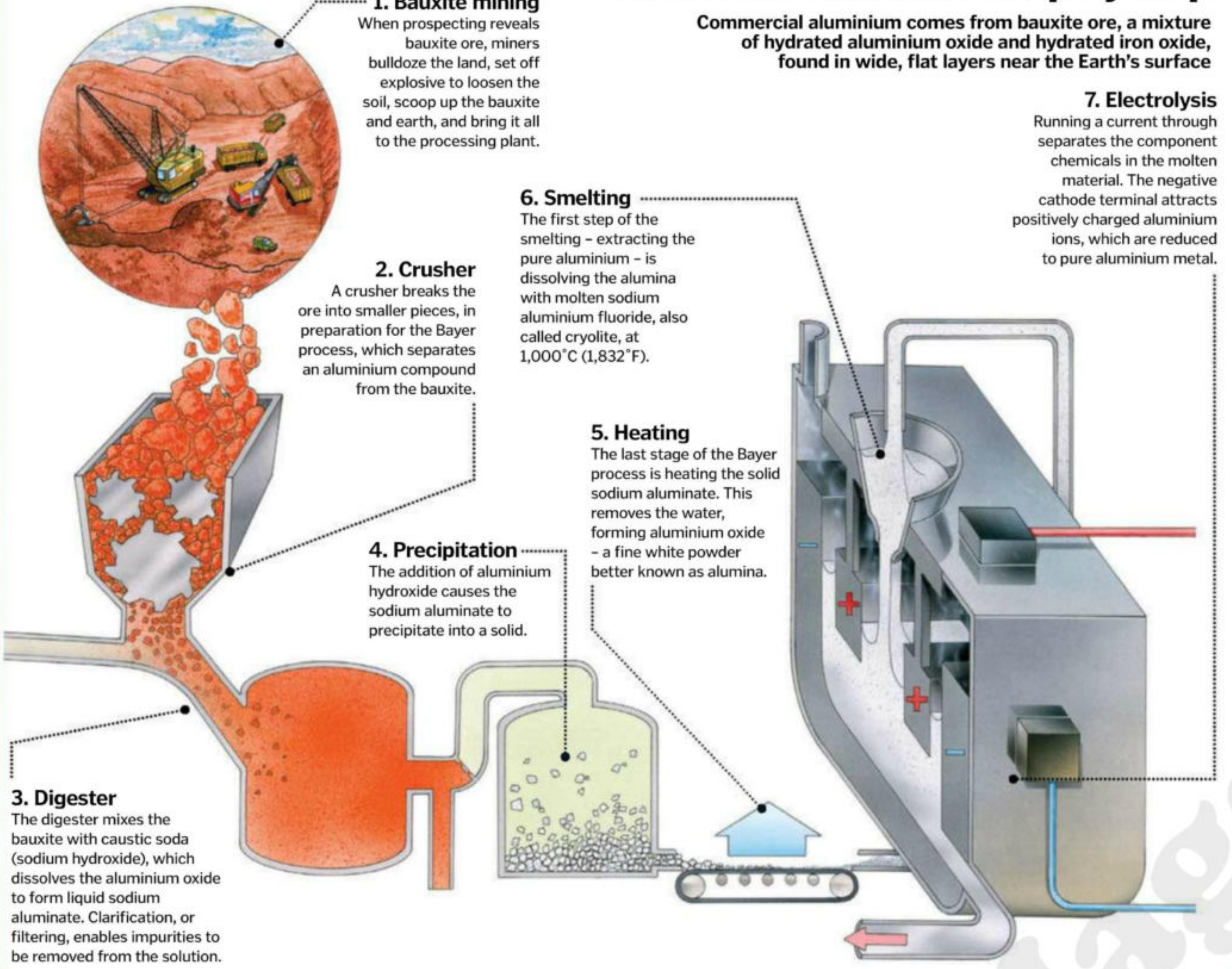
LARGEST ALUMINIUM CAN

In 2002, Taiwan's Vitalon Foods Co unveiled a massive version of its Super Supau sports drink can. It stood 4.7m (15.4ft) tall and weighed a whopping 11 tons!

DID YOU KNOW? *In the 1850s, Napoleon III served his most honoured guests with aluminium plates rather than gold or silver!*

Aluminium extraction step-by-step

Commercial aluminium comes from bauxite ore, a mixture of hydrated aluminium oxide and hydrated iron oxide, found in wide, flat layers near the Earth's surface



1. Bauxite mining
When prospecting reveals bauxite ore, miners bulldoze the land, set off explosive to loosen the soil, scoop up the bauxite and earth, and bring it all to the processing plant.

2. Crusher
A crusher breaks the ore into smaller pieces, in preparation for the Bayer process, which separates an aluminium compound from the bauxite.

3. Digester
The digester mixes the bauxite with caustic soda (sodium hydroxide), which dissolves the aluminium oxide to form liquid sodium aluminate. Clarification, or filtering, enables impurities to be removed from the solution.

4. Precipitation
The addition of aluminium hydroxide causes the sodium aluminate to precipitate into a solid.

5. Heating
The last stage of the Bayer process is heating the solid sodium aluminate. This removes the water, forming aluminium oxide – a fine white powder better known as alumina.

6. Smelting
The first step of the smelting – extracting the pure aluminium – is dissolving the alumina with molten sodium aluminium fluoride, also called cryolite, at 1,000°C (1,832°F).

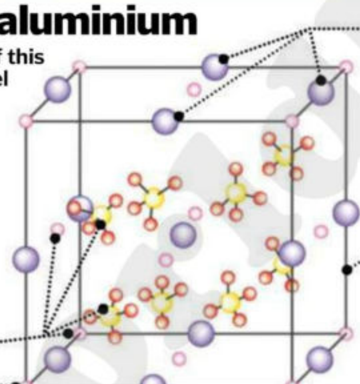
7. Electrolysis
Running a current through separates the component chemicals in the molten material. The negative cathode terminal attracts positively charged aluminium ions, which are reduced to pure aluminium metal.

reaction that could extract it, but his process could only yield minuscule amounts at a time, making thorough experimentation difficult. Following up on Ørsted's discovery, the German chemist Friedrich Wöhler developed a more effective process, and by 1845, he had produced enough aluminium to demonstrate its basic properties. However, the method of extraction was still far too troublesome and slow to support wide-scale production.

In 1854, the French chemist Henri Étienne Sainte-Claire Deville refined the process further, reducing the price from $1,200 per kilogram to $40, which was a huge drop, but still very expensive. That all changed in the 1880s, thanks to two key technological leaps. ▶

Anatomy of aluminium

A look at the makeup of this metal on an atomic level



Aluminium atom
Each aluminium atom consists of a nucleus (yellow) orbited by 13 electrons, including three electrons in the outermost energy level. These valence electrons (red) can be used for chemical bonding.

Chemical bonds
The individual aluminium atoms bond with one another by sharing valence electrons. In addition to the three it already has, each atom borrows extra electrons from other atoms.

Face-centred cube
The bonded atoms form a cubic structure. Together, many cubes form a crystal lattice that makes up solid aluminium material.

"Thanks to recycling, two-thirds of the aluminium ever produced is still in use today"

In 1886, American chemist Charles Martin Hall and French chemist Paul LT Héroult both independently invented a process for extracting aluminium from aluminium oxide. The Hall-Héroult process relies on electrolysis, a means of breaking down chemical compounds into component elements using an electric current. The basic idea is to conduct electricity from a positive terminal (an anode) to a negative terminal (a cathode) via liquid or molten material. Each terminal attracts and repels charged atoms (ions). The positively charged anode attracts negative ions and repels positive ions, and the cathode vice versa.

Scientists had tried to produce aluminium through electrolysis since the 1800s, but had no luck. Hall and Héroult's breakthrough was first dissolving aluminium oxide in molten cryolite (sodium aluminium fluoride). Applying an electric current to this material draws the positive aluminium ions to the cathode, which is typically the vat itself, made from iron lined with graphite.

Hot on their heels in 1888, Austrian chemist Karl Josef Bayer found a way to extract aluminium oxide from bauxite, a naturally occurring ore found in abundance in layers just below the Earth's surface. Geologists drill core samples in likely areas and, on locating bauxite, they clear the ground above with bulldozers. Australia leads global bauxite mining, producing one-third of the total ore.

Together, the Hall-Héroult cost-effective process and the Bayer process, both still in use, ushered in what could be called the 'Aluminium Age'. The metal's properties made it an instant hit. It's lightweight – about a third the weight of steel – but still strong. It's also very ductile, meaning it's easy to draw into a wire or flatten into a sheet, and it's malleable, making it relatively simple to bang it into just about any shape.

Add to that exceptional conduction of heat and electricity, and you've got an incredibly versatile metal. But aluminium's greatest trick may be its resistance to corrosion. Like iron, aluminium is highly reactive to oxygen in the air, but the result of the oxidation reaction is very different. Oxygen and iron react to produce a flaky layer of rust, which falls away, revealing a lower layer of iron, which then oxidises to form yet more rust. In contrast, when aluminium encounters oxygen, the oxidation reaction produces an incredibly hard transparent oxide compound that essentially surrounds the aluminium with a shield that protects it from oxygen and other elements. And best of all, if this protective layer happens to get damaged, it will very quickly reform, reconstructing the shield.

Most aluminium products are actually made from an aluminium alloy – a combination of two metals. The combinations accentuate and amplify certain properties. For example, alloying aluminium with copper improves strength, while an alloy of aluminium and manganese improves resistance to corrosion.

You can turn aluminium into an infinite variety of products, through a number of manufacturing processes. You can cast it into any shape that you want by pouring it into a mould and then letting it cool. You can roll it into malleable sheets, up to a minuscule 0.15 millimetres (0.006 inches) thick. You can forge it to make it super-strong. You can machine it (cutting away material) to produce screws, bolts and other hardware. Finally, you can force it through a die to extrude it into a particular shape, including thin wire.

Aluminium also boasts another major superpower over many other metals: recyclability. Recycling programmes use old aluminium cans to make new ones, at about 30 per cent the cost of making them from scratch. They shred old cans into pieces, melt them in a furnace, form rectangular blocks called ingots, then roll out the ingots into thin sheets from which new cans are cut; believe it or not, this whole process can take just 60 days. Old car parts can undergo a similar process. Thanks to recycling, two-thirds of the aluminium ever produced is still in use today.

Aluminium consumption by market

Building & construction	11.7
Transportation	28.1
Consumer durables	6.0
Electrical	7.0
Machinery & equipment	6.8
Containers & packaging	22.2
Other	3.4
Export	14.8

Source: The Aluminium Association Inc (2008)

World of aluminium

It's durable, light and you can mould it into any shape you want. Little wonder it's everywhere…

Rocket fuel

While you might not be surprised to hear that NASA's space shuttles are made mainly from aluminium, what you may not have realised is that they are also powered by aluminium inside the solid rocket boosters (SRBs). When burned with oxygen, atomised aluminium powder makes for a great fuel. Aluminium powder accounts for about 16 per cent of SRB fuel.

ASM Space Lattice

Aluminium's high strength-to-weight ratio makes it an excellent dome material. Geodesic dome inventor Buckminster Fuller designed this 76m (250ft)-diameter, 80-ton aluminium structure for the American Society for Metals headquarters in Ohio, USA.

Airstream trailers

The quintessential camping trailer took its design from Twenties aeroplane fuselages. Inventor Wally Byam opted for malleable aluminium which he could shape into a fuel-efficient, aerodynamic form.

Ravensbourne College building

Aluminium's weather resistance and sculptural flexibility make it a popular material for building façades. Ravensbourne's building on London's Greenwich peninsula is covered in 28,000 aluminium tiles.

Top of the Washington Monument

When the monument was approaching completion in 1884, the lead engineer selected the novel, relatively rare aluminium for its 23cm (9in) lightning rod pyramid.

HEAD2HEAD
ALUMINIUM ALLOYS

1. STRONG

Titanal
Tensile strength: 700MPa
Austrian manufacturer AMAG revolutionised skis with this super-strong alloy's combination of low weight and high torsion.

2. STRONGER

Weldalite
Tensile strength: 710-720MPa
Developed by Lockheed Martin, Weldalite is a weldable aluminium-lithium alloy widely used in aircraft.

3. STRONGEST

Kobe's alloy
Tensile strength: 780MPa
In 2007, Japanese firm Kobe Steel announced a new unnamed aluminium alloy, fortified with zinc, magnesium and copper.

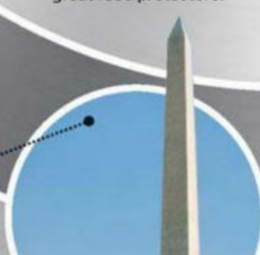
DID YOU KNOW? Aluminium is a common fuel used in fireworks; it also produces white and silver-coloured sparks

Wider world

ISS
Built by Boeing, the US Destiny Laboratory module is a major component of the ISS. The 8.5m (28ft) pressurised unit is made from aluminium and represents the heart of the space station. Aluminium forms part of the outer debris shield too, which is tough enough to vaporise small particles of space junk.

Airbus A380
Aluminium has become the most important material in aerospace history. The world's largest commercial aircraft is 61 per cent aluminium alloy!

Burj Khalifa hotel
The world's tallest manmade structure is also the highest installation whose architectural cladding consists of an aluminium and glazed façade. The total weight of the aluminium used is the same as five Airbus A380s, and the surface area of the curtain wall is 132,190m² (1,422,880ft²).



Everyday world

Aluminium doesn't have the structural strength of steel, the go-to metal for structures like most skyscrapers, and it's not quite as flexible or cheap as plastic, the reigning material for mass-market consumer products, however it's carved out a solid niche in between…

Morning coffee
Nespresso's airtight coffee capsules are made of aluminium to keep the product fresh, away from air, light and humidity.

Automobiles
Aluminium keeps this all-electric car lightweight, while still strong and rigid. Each car begins life as a 9,072kg (20,000lb) aluminium coil, which is stamped into sections.

Computers
Many of Apple's devices are made of anodised aluminium, which not only polishes and toughens a product, but also provides a way of adding colour via oxidation, as seen in multicoloured iPods.

Drinks cans
On top of being light and cheap, the king of aluminium products is 100 per cent recyclable. 113,204 cans are recycled every minute.

Kitchen foil
As a natural barrier to light, oxygen, moisture and just about anything airborne, including bacteria, flexible aluminium sheets are great food protectors.

Phone lines
Aluminium is a great electrical conductor, like copper but much lighter. Its low weight makes it an ideal choice for elevated power and phone lines.

Pots and pans
Much modern cookware includes aluminium, which boasts excellent thermal conductivity. But possible links to neurodegenerative disease have made it somewhat controversial.

AMAZING VIDEO! SCAN THE QR CODE FOR A QUICK LINK

Watch a Slinky appear to levitate in thin air!

www.howitworksdaily.com

DID YOU KNOW? *The Slinky was first sold in 1945 at Gimbels department store in Philadelphia, PA, USA*

Amazing Slinky physics

Despite its basic appearance, the science behind this toy is pretty complex

The Slinky is a simple toy, consisting of nothing more than a helical spring made of metal or plastic. Simple it may be, but don't underestimate the scientific principles at play; you'll learn a lot about a range of forces by playing with this toy.

The best way to see these in action is to watch a Slinky as it tumbles down a flight of stairs. Given a little nudge off the top step, the toy then independently falls from one step to the next in a fluid manner (see the 'Slinky step-by-step' boxout for more information).

Within this seemingly straightforward descent, the Slinky demonstrates the effects of friction and inertia, potential and kinetic energy, the consequences of momentum and behaviour consistent with compression waves – the latter granting its distinct motion.

Inertia is the resistance of any physical object to a change in its state of motion or rest, such as the Slinky standing on its end, unmoved by any outside force. This inertia is aided by the effects of friction, such as exerted on the spring by the Earth's atmosphere, as well as between its own material and the surface on which the toy is lying (eg carpet).

Despite inertia, however, objects have potential energy, which is the energy of an object granted by its position and particular makeup; a Slinky has potential energy due to its metal/plastic body, helical shape and position at the top of a flight of stairs, for example. This potential energy is 'released' and converted to kinetic energy – the form of energy governed by motion – when acted on by an external force (in the case of the Slinky, this is when it is pushed over the top step).

Finally, moving objects possess momentum, which is the product of their combined mass and velocity. Objects with a larger momentum require more energy to move and to stop, while those with low mass and velocity have less momentum. As such, a metal Slinky is better at moving down stairs than plastic variants, as its greater momentum makes the toy more unbalanced between each step.

Slinky step-by-step

1 Inertia
At its starting point the Slinky resists changes in motion due to friction, and demonstrates inertia.

2 Kinetic
When an outside force exerts itself (ie someone pushing it), potential energy converts into kinetic energy.

3 Gravity
Due to the force of gravity the Slinky's top end begins to fall towards the next step, with its kinetic energy propagating along its length as a compression wave.

4 Momentum
As the rear of the Slinky catches up, momentum makes it overshoot the step below.

5 Friction
The rear of the Slinky then restarts the process from step 2. It shouldn't stop till kinetic energy is overcome by friction (ie when the stairs run out).

©Alamy

"There are five types of WBC, and each cell works in a different way to fight a variety of threats"

How do white blood cells work?

One of the body's main defences against infection and foreign pathogens, how do these cells protect our bodies?

White blood cells, or leukocytes, are the body's primary form of defence against disease. When the body is invaded by a pathogen of any kind, the white blood cells attack in a variety of ways; some produce antibodies, while others surround and ultimately devour the pathogens whole.

In total, there are five types of white blood cell (WBC), and each cell works in a different way to fight a variety of threats. These five cells sit in two groupings: the granulocytes and the agranulocytes. The groups are determined based on whether a cell has 'granules' in the cytoplasm. These granules are digestive enzymes that help break down pathogens. Neutrophils, eosinophils and basophils are all granulocytes, the enzymes in which also give them a distinct colouration which the agranulocytes do not have.

As the most common WBC, neutrophils make up between 55 and 70 per cent of the white blood cells in a normal healthy individual, with the other four types (eosinophils, basophils, monocytes and lymphocytes) making up the rest. Neutrophils are the primary responders to infection, actively moving to the site of infection following a call from mast cells after a pathogen is initially discovered. They consume bacteria and fungus that has broken through the body's barriers in a process called phagocytosis.

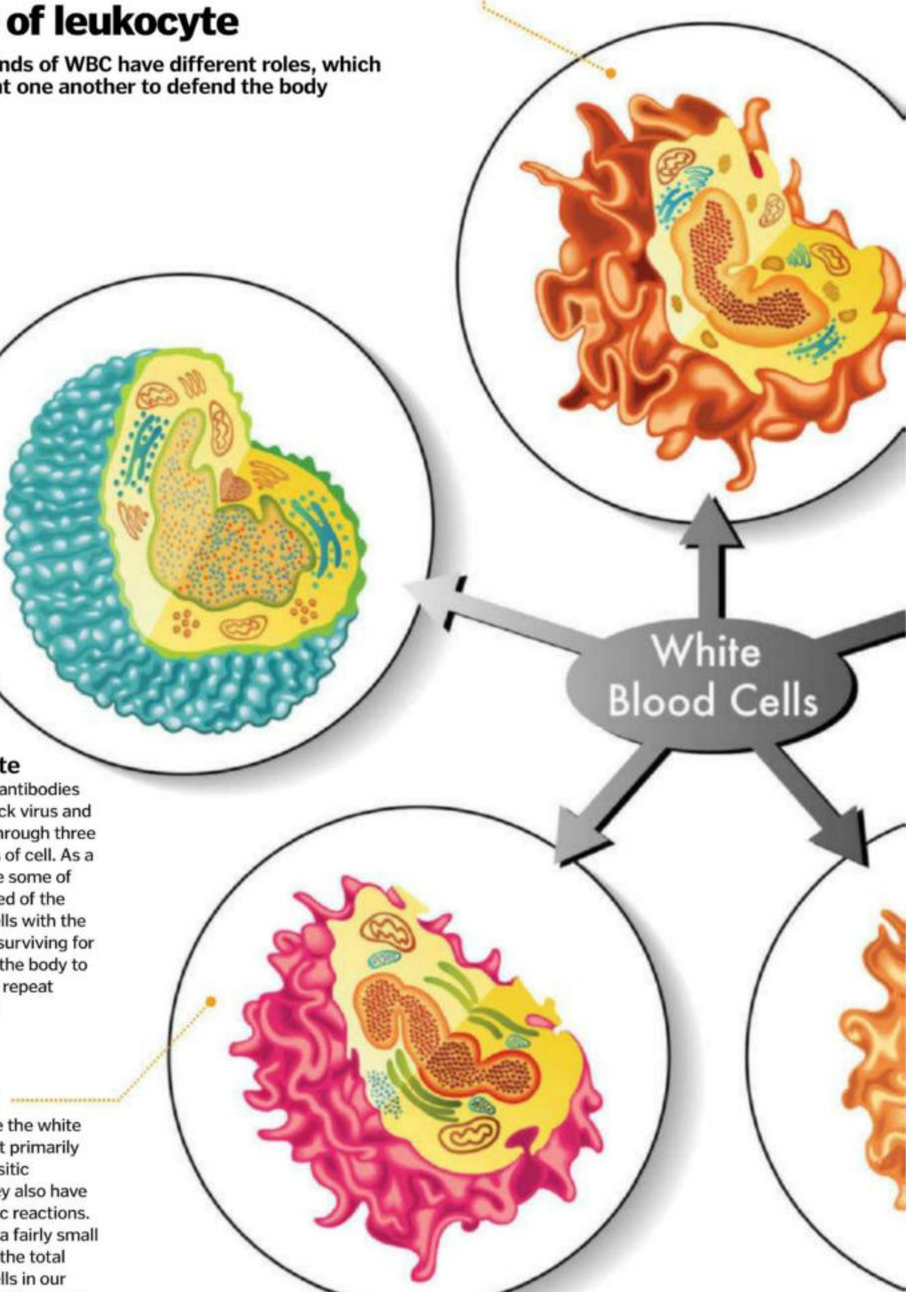
Lymphocytes – the second-most common kind of leukocyte – possess three types of defence cells: B cells, T cells and natural killer cells. B cells release antibodies and activate T cells, while T cells attack diseases such as viruses and tumours when directed, and regulatory T cells ensure the immune system returns to normal after an attack. Natural killer cells, meanwhile, aid T cell response by also attacking virus-infected and tumour cells, which lack a marker known as MHC.

The remaining types of leukocyte release chemicals such as histamine, preparing the body for future infection, as well as attacking other causes of illness like parasites.

Types of leukocyte

Different kinds of WBC have different roles, which complement one another to defend the body

Monocyte
Monocytes help prepare us for another infection by presenting pathogens to the body, so that antibodies can be created. Later in their life, monocytes move from the bloodstream into tissue, and then evolve into macrophages which can conduct phagocytosis.



Lymphocyte
These release antibodies as well as attack virus and tumour cells through three differing types of cell. As a group, they are some of the longest lived of the white blood cells with the memory cells surviving for years to allow the body to defend itself if repeat attacks occur.

Eosinophil
Eosinophils are the white blood cells that primarily deal with parasitic infections. They also have a role in allergic reactions. They make up a fairly small percentage of the total white blood cells in our body – about 2.3 per cent.

THE STATS
LEUKOCYTES

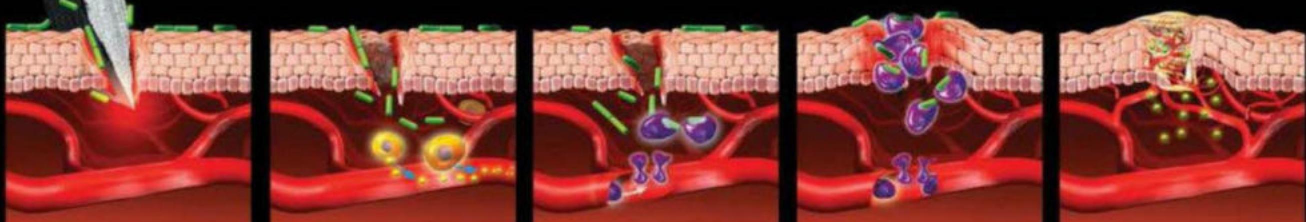
NEUTROPHIL LIFETIME (HOURS) 6 | MACROPHAGE DIAMETER **80mm** | WBCS WHICH ARE BASOPHILS 4 in 1,000

BLOOD COMPOSITION **1%** | BACTERIA CONSUMED BY EACH NEUTROPHIL 5-20 | NUMBER OF WBCS IN A DROP OF BLOOD **7,000**

DID YOU KNOW? *WBCs have colour but appear white when blood is put through a centrifuge, hence their group name*

White blood cells at work

The body has various outer defences against infection, including the external barrier of the skin, but what happens when this is breached?



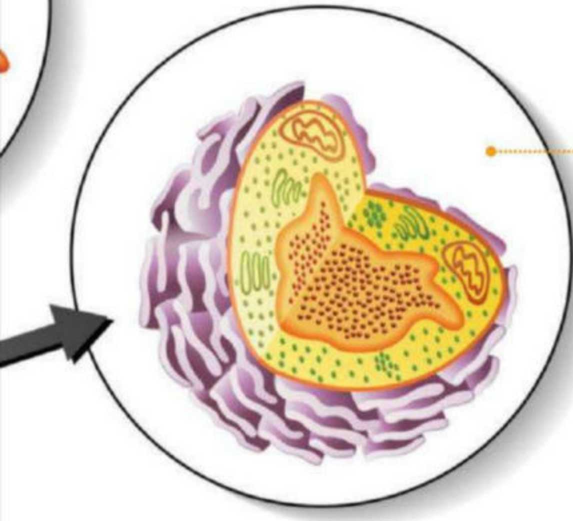
Skin breach
A foreign object breaks through the skin, introducing bacteria (shown in green) into the body.

Mast cells
Mast cells release cytokines and then WBCs are called into action to ensure the infection does not spread.

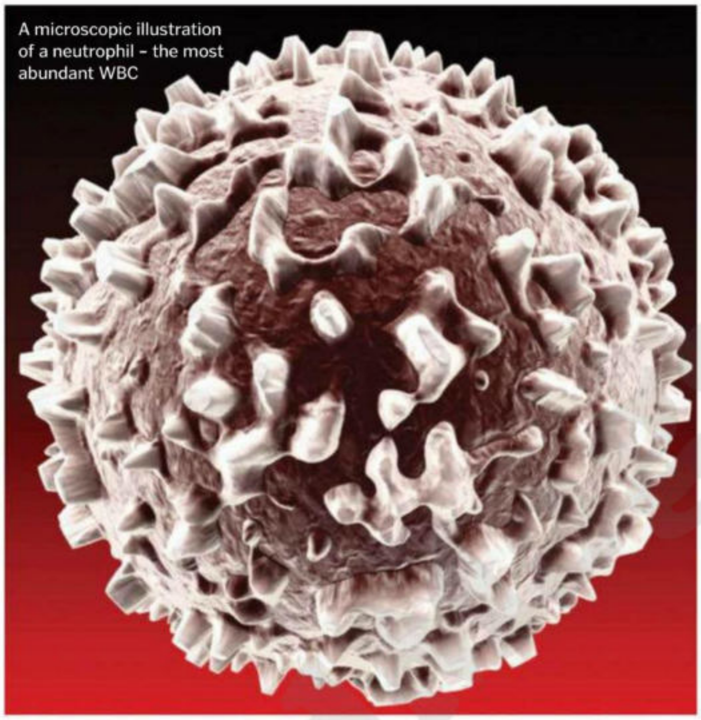
WBCs arrive
Macrophages move to the site via the bloodstream to start defending against invading bacteria.

Macrophages consume bacteria
Bacteria are absorbed into cytoplasm and broken down by the macrophages.

Healing
Following removal of the bacteria, the body will start to heal the break in the skin to prevent further infection.



Basophil
Basophils are involved in allergic response via releasing histamine and heparin into the bloodstream. Their functions are not fully known and they only account for 0.4 per cent of the body's white blood cells. Their granules appear blue when viewed under a microscope.



A microscopic illustration of a neutrophil – the most abundant WBC

Neutrophil
Neutrophils are the most common of the leukocytes. They have a short life span so need to be constantly produced by the bone marrow. Their granules appear pink and the cell has multi-lobed nuclei which make them easily differentiated from other types of white blood cell.

A faulty immune system

If the immune system stops working properly, we are at risk of becoming ill. However, another problem is if the immune system actually goes into overdrive and starts attacking the individual's cells, mistaking them for pathogens. There are a large number of autoimmune ailments seen across the world, such as Crohn's disease, psoriasis, lupus and some cases of arthritis, as well as a large number of diseases that are suspected to have autoimmune roots.

We can often treat these conditions with immunosuppressants, which deactivate elements of the immune system to stop the body attacking itself. However, there are drawbacks with this treatment as, if the person exposes themselves to another pathogen, they would not have the normal white blood cell response. Consequently, the individual is less likely to be able to fight normally low-risk infections and, depending on the pathogen, they can even be fatal.

> "After the initial sting the venom sac can continue to pump venom into the victim"

What is thermoregulation?

Why do humans need to maintain a constant internal body temperature of 37°C?

Your cells work best when the temperature inside your body is 37 degrees Celsius (98.6 degrees Fahrenheit). Thermoregulation is a homeostatic function that enables you to maintain this core temperature independent of how hot or cold your surroundings are.

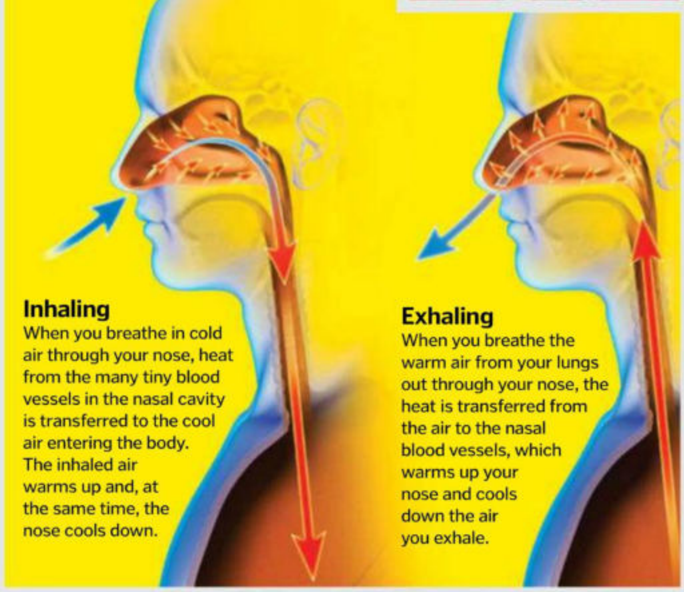
Humans regulate body temperature via a combination of internal processes and external actions. The latter includes behavioural responses, such as heading for shade when we're exposed to too much Sun.

If that doesn't help, the body also has a number of automatic responses that help regulate temperature. The main organ involved is the skin, which is controlled by the autonomic nervous system. When your surroundings heat up, the brain triggers a series of chemicals which tell your blood vessels to dilate (widen). This not only brings warm blood to the surface of the skin where it can more easily radiate heat away, but it also releases sweat through the pores. The body emits heat to vaporise the moisture from the skin, cooling us in the process.

Conversely, when your surroundings grow cold, your blood vessels constrict (narrow), reducing the flow of blood to the surface. The hairs on your skin stand on end and you may shiver and get goosebumps as the skin's arrector pili muscles contract, pulling the hairs erect to trap air near the skin's surface.

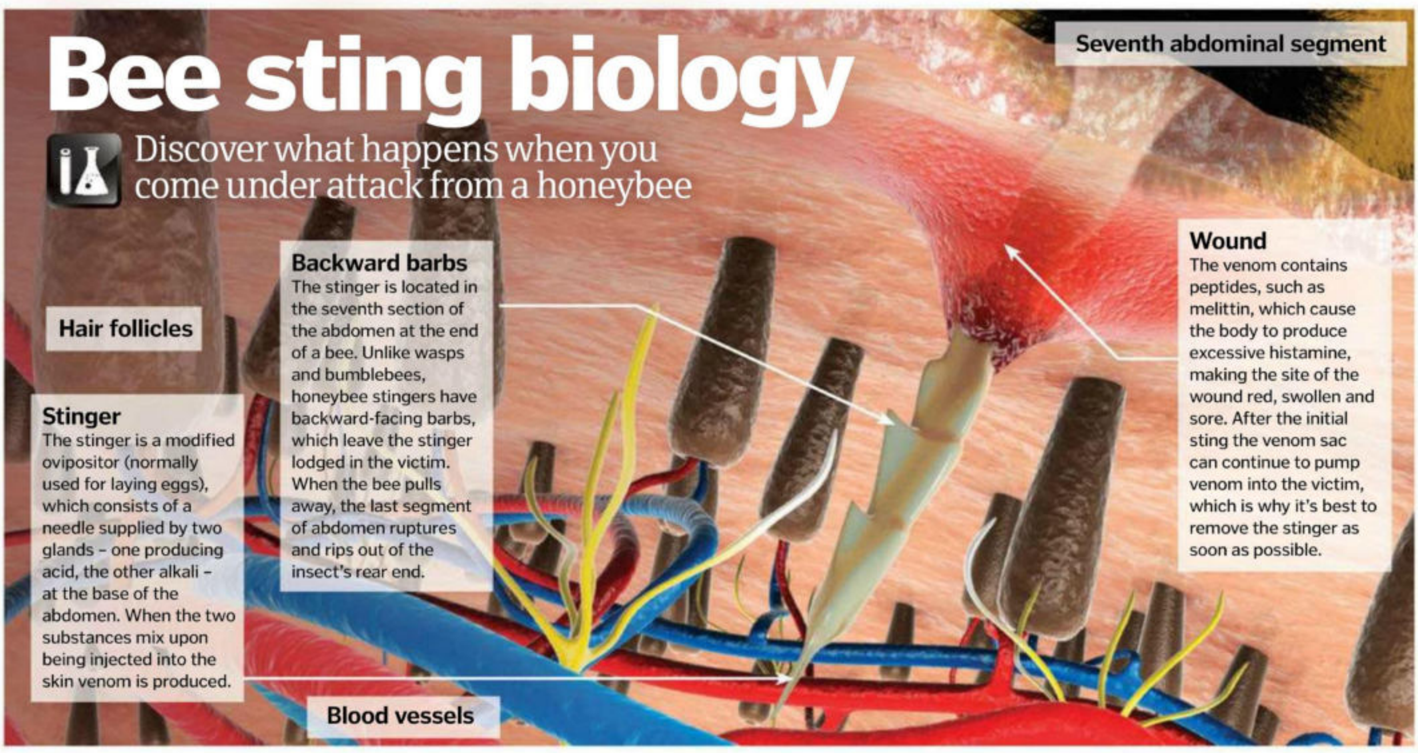
Thermoregulation in action

Learn how breathing through your nose can regulate temperature



Bee sting biology

Discover what happens when you come under attack from a honeybee



Batteries
Aerographite could be used on the electrodes of li-ion batteries, allowing only a tiny amount of electrolyte to be used, reducing the battery's overall weight.

Non-conductive plastic
Non-conductive plastic could be transformed with the introduction of aerographite, removing the effects of static without adding weight.

Satellites
Another possible use is in satellites and aircraft. These machines must cope with lots of vibration, which could be mitigated by using aerographite.

DID YOU KNOW? Aerographite was announced in June 2012 by the Hamburg University of Technology and Kiel University

World's lightest material

Discover how Aerographite was developed and what unique applications it might offer in the future

Aerographite is a revolutionary new material that consists of a network of porous carbon tubes. These tiny tubes are three-dimensionally interwoven at both a nano and micro level, creating a substance that weighs only 0.2 milligrams per cubic centimetre (0.0001 ounces per cubic inch); it is about 99.99 per cent air.

Aerographite appears jet-black – as its structure means that it absorbs almost all visible light, can conduct electricity and, most importantly, is incredibly ductile – the latter quality allowing it to be drawn out and manipulated, something that grants it a wide range of applications.

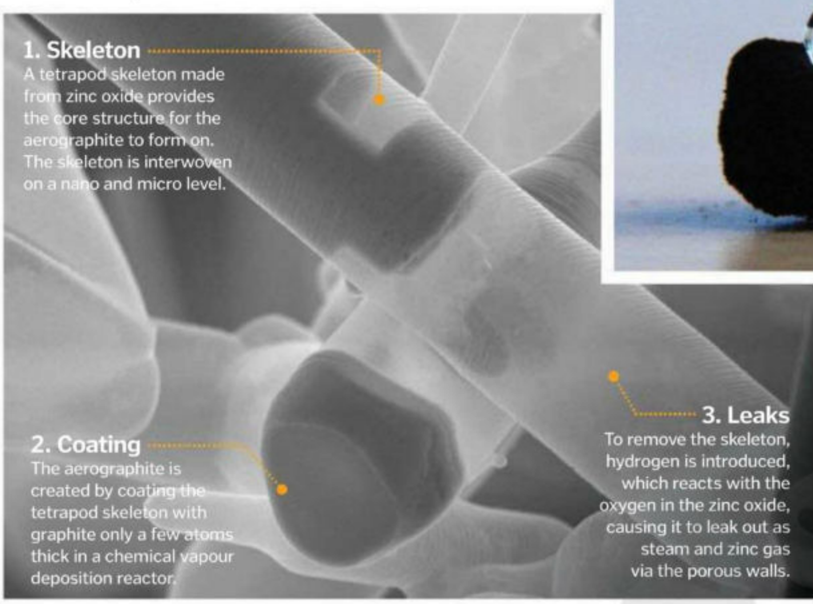
The reason that aerographite is so light is three-fold. Firstly, the carbon tubes are not solid but actually empty shells. Secondly, carbon has a very low atomic mass – far more so than the previous lightest material in the world which was nickel based. And thirdly, in addition to the tubes being hollow, their walls are also porous. Combined, this trio of characteristics generates a material that is 75 times lighter than Styrofoam and a staggering 56,700 times lighter than lead.

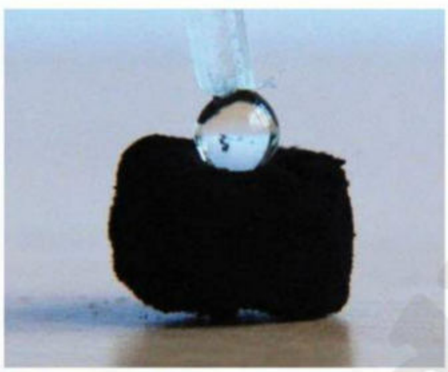
Such a complex material requires, as you would expect, an equally complex manufacturing process. Aerographite is made by first building a kind of skeleton, or frame, out of crystallised zinc oxide, which is achieved by heating zinc oxide powder to 900 degrees Celsius (1,652 degrees Fahrenheit) in an oven. From this crystallised material, a kind of pill is created in which a matrix of zinc-oxide micro and nano-tetrapods develop. The four-sided jack-shaped tetrapods interweave and construct a stable entity of particles to form the skeleton.

The skeleton-filled pill is then deposited into a reactor for chemical vapour deposition. Here, a streaming gas atmosphere enriched with carbon covers the skeleton with a graphite coating only a few atomic layers thick. It is this coating that creates the web-like structures of the aerographite. Once this is achieved, hydrogen is introduced to the chamber, which reacts with the oxygen in the zinc oxide tetrapod skeleton, causing it to vaporise and leak out through the porous walls of the graphite coating. The culmination of this process leaves hollow tubes of super-light aerographite, which can then be extracted.

How is aerographite made?

We take a look at the unique material under the microscope to reveal how it forms





Above shows a block of aerographite supporting a drop of water. It appears black in colour as its carbon tubes absorb almost all visible light

Aerographite comparison

1 Lead
With this heavy metal clocking in at 11,340 milligrams per cubic centimetre (6.5549 ounces per cubic inch), aerographite smashes it in terms of weight, with the new material roughly 56,700 times lighter.

2 Aluminium
The supposedly super-light metal aluminium weighs 2,700 milligrams per cubic centimetre (1.5607 ounces per cubic inch). Nevertheless, it is still nowhere near as light as aerographite, which is 13,500 times lighter than it.

3 Bone
Super-strong and light bone weighs 1,850 milligrams per cubic centimetre (1.0694 ounces per cubic inch), which is over six times lighter than lead. But this organic material remains some way off aerographite, with the latter weighing 9,250 times less.

4 Cork
Cork is so light that it can float on water. However, at 160 milligrams per cubic centimetre (0.0924 ounces per cubic inch), cork is still approximately 800 times heavier than aerographite.

5 Nickel microlattice
Famous for being so light it could rest on a dandelion seed head, at 0.9 milligrams per cubic centimetre (0.0005 ounces per cubic inch) aerographite is impressively four times less heavy.

A replica of Thomas Edison's original light bulb which was patented in 1880

The electric light bulb

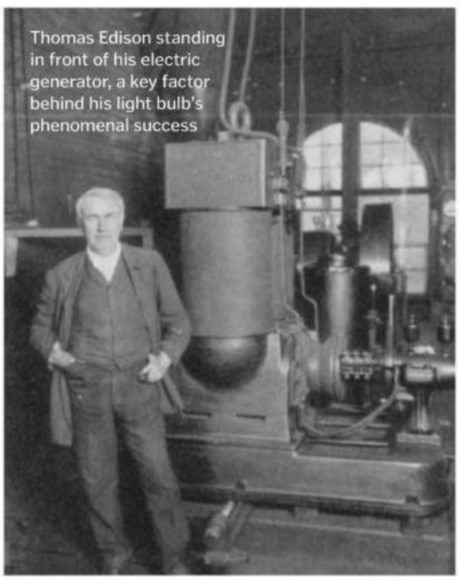
HIW sheds some light on one of the most world-changing inventions

Today the electric light bulb is an essential part of society, with virtually all streets, homes and vehicles installed with one. The invention has literally lit up the Earth and transformed how we live.

The beginning of the journey to the electric light bulb began in 1799 when Italian physicist Alessandro Volta invented the voltaic pile (battery). The details of the battery soon spread through Europe, with many scientists replicating it and experimenting with its power-giving capabilities. One of the most notable of these scientists was British physicist Sir Humphry Davy who built one at the Royal Institution in 1802. In 1810, after much experimentation, Davy invented the first arc lamp, a temporary electric light source enabled by connecting two carbon rods to the battery's terminals and bringing them to within a couple of millimetres of each other. This caused the electric current to jump between the two, creating a bright plasma stream that illuminated the immediate surrounding area.

Unfortunately, the intensity of the plasma soon caused the carbon rods to burn away and the invention did not gain commercial traction. However, the use of carbon and a variety of other metals as electrodes and filaments did, leading a number of scientists to create crude lights. None were sustainable, however.

The next major breakthrough came in the realisation that the electrodes/filaments used in incandescent lights could be protected from quick destruction by placing them within a vacuum filled with an inert gas (as demonstrated by Warren de la Rue in 1840). This, along with the later discovery that filaments could be carbonised, allowed basic light bulbs to be created that, rather than lasting seconds or minutes, would work for hours and eventually days. Indeed, throughout the mid-19th century numerous scientists, and even an illusionist, showed such bulbs to their friends and at public demonstrations.



Thomas Edison standing in front of his electric generator, a key factor behind his light bulb's phenomenal success

This series of prototypes culminated in 1879 when Joseph Swan successfully demonstrated and then sold a light that used a single coil of carbonised artificial cellulose fibre embedded within an airless glass bulb. This was the first commercially sold incandescent light bulb. Critically though, its adoption was only on a very small scale as, despite the bulb proving resilient, the power source needed was largely unavailable, with no electric infrastructure in place to support a wide-scale rollout.

This set the scene for Thomas Edison, who in 1880 successfully patented his own light bulb, which aside from being an improved design to that of Swan, was backed up by Edison's own electric generator, a package that would enable him to largely corner the new market for electric lighting that was set to take off.

Light bulb evolution

After Thomas Edison brought light bulbs to the mass market, what happened next?

1903
Tantalum

After the carbon rod light bulb, scientists test new filament materials to improve brightness. In 1903 Siemens and Halske try using tantalum.

1906
Sinter-lating

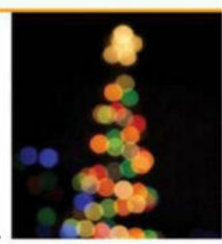
The General Electric Company, which was co-founded by Thomas Edison, patents a method of making filaments from sintered tungsten.

1913
Inert

American physicist Irving Langmuir discovers that filling bulbs with inert gas rather than just a vacuum results in twice the luminous efficacy.

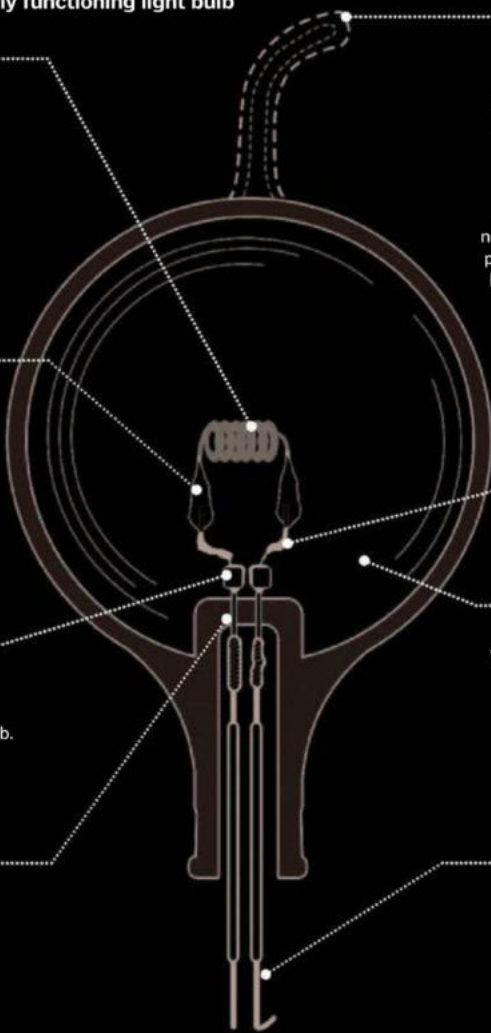
1917
Festive lighting

Electric Christmas lights see a boom in 1917 when teen Albert Sadacca is inspired to start making them after a fire in NYC caused by candles in a tree.



Inside a carbon filament light bulb

We take a look at Thomas Edison's 1880 electric lamp, arguably the first fully functioning light bulb



Carbon spiral
Edison used a carbonised (achieved by heating it to high temperatures), high-resistance filament, which was coiled in the centre by winding it around a bobbin.

Filament ends
As the filament coil was very thin and delicate it could not be attached to the platinum lead wires directly. Instead lamp-black and tar were used at the ends as a mould around each connection, ensuring its stability.

Clamps
The platina wires were attached to the platinum lead wires with two mini clamps encased in the bulb.

Leading wires
The light bulb's leading wires were made out of platinum due to its high melting point of 1,772°C (3,222°F) and low resistance compared to the filament.

Vacuum tube
To create a vacuum within the bulb a vacuum tube was blown that attached to a pump. After exhaustion, this entrance was hermetically sealed.

Platina wires
The carbon filament was not directly attached to the platinum lead wires via the lamp-black and tar mould. Instead two platina contact wires were used.

Vacuum bulb
The bulb for the filament was roughly spherical and made from glass. The inside was a vacuum – something achieved by drawing out the oxygen through a top-mounted vacuum tube.

Copper wires
Electric current for the light bulb was supplied from a battery/generator through conventional copper wires.

Top 5 facts: light bulbs

1 Evaporation
Under sustained use the filament of modern-day tungsten bulbs will evaporate before condensing on the inner surface of the glass envelope, blackening it.

2 Halogen
Halogen lamps reduce evaporation of their filament and the darkening of the surrounding glass by filling the lamp with halogen gas at a very low pressure.

3 Inefficient
Despite modern bulbs lasting for lengthy periods, about 90 per cent of the power they consume is emitted as heat, rather than light.

4 Bulb boom
In 1885 there were estimated to be about 300,000 incandescent lights in use, a number which then exploded over the subsequent decades up to 795 million by 1945.

5 Old-timer
The Livermore Centennial Light Bulb at a fire station in California, USA, has been burning non-stop since 1901. It is the record holder for longest operational bulb in the world.

Bright sparks: the race to the commercial light bulb

Sir Humphry Davy
In 1802 British scientist Sir Humphry Davy used his large battery to pass a current through a thin strip of platinum. The experiment worked, but the platinum did not glow very brightly and wore out too quickly to be practically implemented into a lamp.

Warren de la Rue
In 1840 chemist and astronomer Warren de la Rue enclosed a platinum coil in a vacuum tube and passed an electric current through it. This was one of the first true light bulbs as we know them today, however its cost and complexity made it impractical to roll out.

Jean Robert-Houdin
This illusionist created his own incandescent light bulbs and showed them publicly at his estate in 1852. Again, they were curiosities and no practical production process or cost-efficient materials meant they couldn't be produced commercially.

Alexander Lodygin
In 1872 Russian Lodygin obtained a patent for an incandescent light bulb that used carbon rods in a nitrogen-filled, sealed bell glass receiver. He later moved to the US and applied for many patents, showing a molybdenum filament at the Paris World Fair in 1900.

Joseph Swan
This British physicist arguably created one of the first sustainable light bulbs, demonstrating his carbon rod bulbs in 1878-9. He received a patent and began installing them in a few homes and theatres. He later partnered with Edison and set up the Ediswan Electric Company.

1937
Krypton-light
Production of light bulbs filled with the noble gas krypton begins in Hungary.

1977
Energy saving
Energy-saving light bulbs begin to be introduced to the market, leading to the generation of compact fluorescent lamps.

1991
Long-lasting
The electronics company Philips produces a fluorescent light bulb that lasts 60,000 hours through the process of magnetic induction.

2010
Green light
In many countries worldwide incandescent light bulbs begin to be phased out in favour of more eco-friendly LED and fluorescent types.

2012
Lights out
From 1 September, an EU directive bans all retailers from selling incandescent bulbs. It's hoped this will save an annual 39 terawatt hours by 2020.

Stars might look like tiny specks, but these massive superhot bodies are the heart of every planetary system and ultimately sustain life. As well as lots of astral trivia, learn about the giant dwarf planet Eris and how Galileo revolutionised astronomy.

LEARN MORE

20 amazing facts about stars

The answers to your burning questions about some of the most violent and dramatic objects in the universe

Human beings have been making up stories and theories to explain the stars since prehistoric times, and the study of the stars has played a crucial role in the development of science and technology throughout history, inspiring everything from calculus to clockwork. But the idea that the stars might be 'suns' in their own right, unimaginably distant from Earth, is a surprisingly recent one, and it's only in the past century or so that astronomers have really got to grips with the true variety of stars.

Along the way, they've discovered that the Sun is really nothing special – a distinctly 'average Joe' compared to some of the extremes found elsewhere in our galaxy and the wider cosmos. And the journey of discovery is still ongoing. While we now have convincing theories to explain the birth and death of stars, their internal power sources and their varied properties, new telescopes and satellites are continually revealing surprising new bodies that challenge our thinking and continue to inspire us with awe and wonder.

1. Are we stardust?

Absolutely – if it weren't for generations of stars, the universe would contain nothing more than the light elements that formed in the Big Bang. Everything else, from the calcium in our bones to the carbon in our DNA, ultimately comes from stars. Deep in their cores, nuclear fusion forces the nuclei of lightweight atoms together to form heavier ones, and the heavier the star, the further this process goes. Stars like the Sun create elements such as carbon, nitrogen and oxygen through their lives, and then scatter them across space when they die. Heavier stars release iron, gold and uranium when they go supernova.

2. What colour can stars be?

The colour of any star is a mix of different wavelengths of light, ranging from high-energy, short-wavelength blue and violet light emitted by the hottest materials, to lower-energy, longer-wavelength red and orange emitted by cooler gases. White stars represent an even balance between the two.

5 TOP FACTS
RECORD HOLDERS

WISE 1828+2650
1 Discovered only in 2011, this brown dwarf, or failed star – just nine light years from Earth – has a surface temperature that is cooler than the human body at just 25°C (80°F).

Eta Carinae
2 The brighter component of unstable double star Eta Carinae is a blue hypergiant – perhaps the hottest star known with a temperature of 37,000°C (67,000°F).

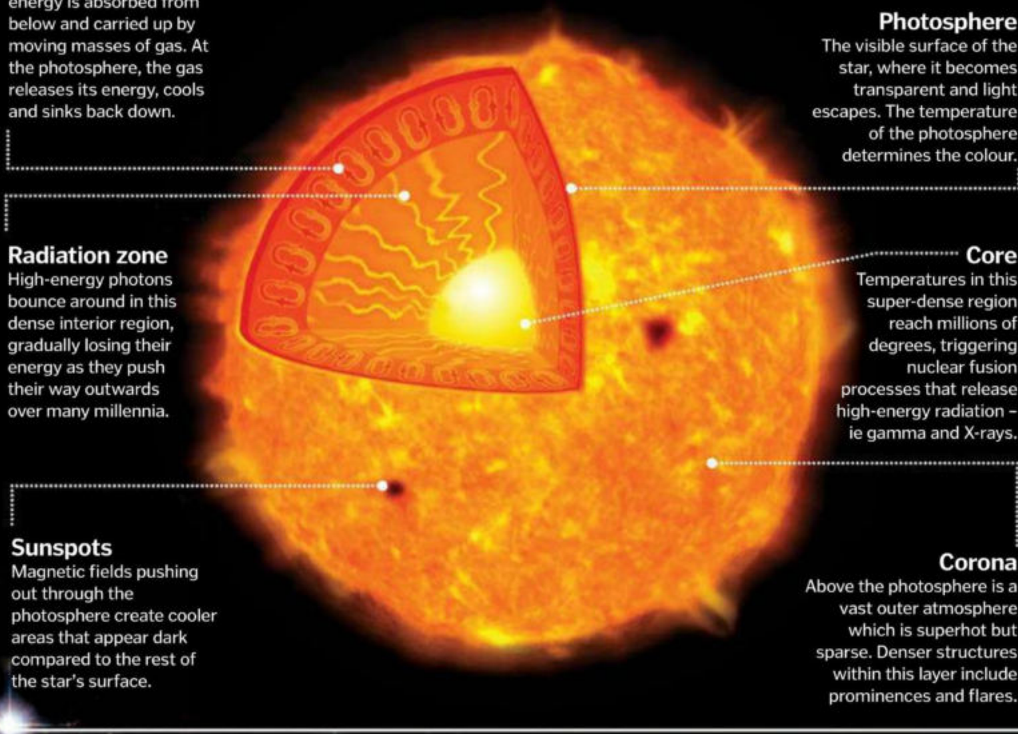
VFTS 102
3 The bright blue giant VFTS 102 sits 160,000 light years away in the Large Magellanic Cloud galaxy. Spinning 300 times faster than the Sun, it bulges out noticeably at its equator.

R136a1
4 Both the brightest and the heaviest star, R136a1 lies at the heart of the Tarantula Nebula, a huge region in the Large Magellanic Cloud. It has a mass of around 265 Suns!

HE 1523-0901
5 The oldest-known star has an estimated age of 13.2 billion years. This suggests it formed from the remains of the very first stars, about 500 million years after the Big Bang.

DID YOU KNOW? Astronomers estimate that the Milky Way alone contains 200-400 billion stars

3. What's inside a star?

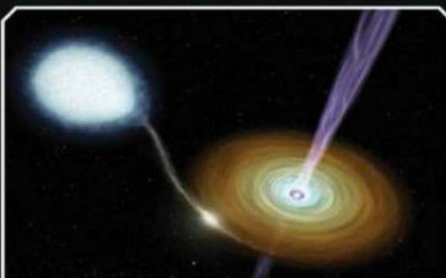


4. Why do stars twinkle?

They don't. Their light gets distorted by churning gases in Earth's atmosphere – hence why telescopes are built on mountains, above the bulk of the air. We only notice the twinkling as stars are tiny points of light; planets don't twinkle as they're close enough to appear as tiny discs.

5. Which is the farthest star that we can see?

Ignoring occasional flare-ups such as supernovas, the farthest star we can reliably see with the naked eye is the obscure V762 Cassiopeiae, which is just visible under dark skies and is around 16,300 light years away. The most distant well-known star, meanwhile, is Deneb, the brightest star in the constellation of Cygnus, the Swan. It lies a still impressive 2,600 light years away and is the 19th brightest star in the sky, suggesting it is around 200,000 times more luminous than the Sun.



6. What is a neutron star?

Neutron stars are extreme stellar remnants formed after a giant star goes supernova. When the star runs out of fuel, it collapses under its own weight, creating a huge shockwave that compresses the core from the size of our Sun to roughly the size of London. Atomic nuclei in the core are torn into their subatomic components and protons are transmuted into yet more neutrons that can reach crazy densities: a pinhead of neutron star material can weigh as much as a fully laden supertanker!

7. How are stars named?

The brightest stars have proper names that often originated with Ancient Greek or Arabic astronomers – for instance, Sirius, the brightest star in the night sky, has a name derived from the Greek for 'scorcher'. The bright stars in each constellation are also named with Greek letters in alphabetical order – so Sirius is also Alpha Canis Majoris.

8. Can we tell if the stars we see have died?

Stars take millions or billions of years to move through their life cycles, but the light from stars in our galaxy usually spends a few thousand years at most travelling to Earth. On the law of averages, then, it's pretty unlikely that a star will have died in the intervening time, but there are some exceptions, eg Eta Carinae might have already exploded.

9. How can a star burn with no oxygen in space?

Blame astronomers for the misleading word 'burn' – stars aren't going through the same kind of combustion we see on Earth. Instead, stars feed off their hydrogen fuel by forcing individual nuclei together until they transmute into helium and eventually other elements in a process known as nuclear fusion.

10. What exactly is a white dwarf?

White dwarfs are the superhot, burnt-out cores of stars like the Sun, exposed when a dying red giant star sheds its outer layers. With no nuclear fusion left to support it, the core collapses under its own weight until it is about the size of Earth, but typically still contains roughly half a Sun's mass of material.

"Ultimately, all stars scatter material across space to produce the next generation"

11. What are main-sequence stars?

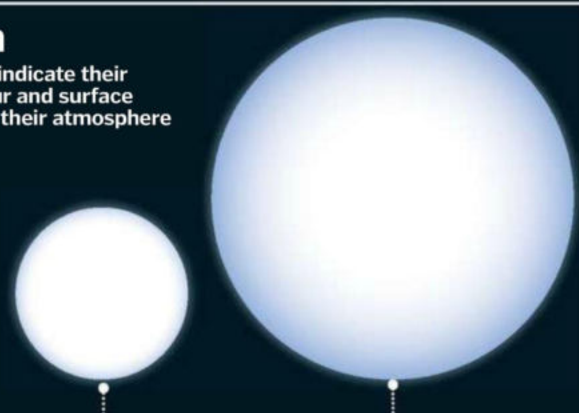
Most stars spend the majority of their lives in what astronomers call the 'main sequence'. This phase marks the period when they generate energy by nuclear fusion of hydrogen into helium. A star's position on the main sequence is governed by its mass – the lightest main-sequence stars are small, red and faint, while the heaviest are big, blue and brilliant.

Spectral classification

Astronomers class stars with letters that indicate their spectral type, broadly linked to their colour and surface temperature as well as elements found in their atmosphere

M-type stars
The least massive main-sequence stars shine with less than one-100,000th of the Sun's light and have cool red surfaces.

A-type stars
White main-sequence stars, with around twice the Sun's mass, tend to have surface temperatures of 10,000°C (18,000°F).



K-type stars
Main-sequence stars with perhaps half the mass of the Sun are larger and brighter, glowing orange with temperatures of 4,500°C (8,100°F).

G and F-type stars
Stars with a similar mass to the Sun appear yellow, with surface temperatures of around 5,500°C (9,900°F).

B-type stars
Above about two solar masses, main-sequence stars are structurally different from those like the Sun. Hundreds of times more luminous, their surfaces glow blue-hot.

O-type stars
These rare blue stellar heavyweights squander their fuel rapidly, growing to enormous sizes and shining a million or so times brighter than our Sun.

12. What's the difference between a nova, supernova and hypernova?

Novas are relatively small explosions in double star systems. They come about when a white dwarf's intense gravity tugs material away from a companion star. Gas piles up around the white dwarf and eventually becomes dense enough to ignite in a burst of nuclear fusion. Most supernovas, meanwhile, mark the deaths of massive stars and the formation of neutron stars. They are triggered when a shockwave tears through the outer layers of a dying star, igniting a firestorm of nuclear fusion. Finally, hypernovas are ultra-energetic supernovas marking the birth of black holes and associated with the release of intense gamma-ray bursts.

13. Which stars are the biggest and smallest?

The biggest known star is an unstable red hypergiant called NML Cygni, about 5,500 light years from Earth – its diameter of around 1,600 Suns makes it close to twice the size of Betelgeuse. The smallest star is OGLE-TR-122b, a tiny red dwarf only slightly larger than Jupiter and with just a tenth the mass of the Sun. Anything smaller is a brown dwarf.

14. Where is Betelgeuse?

With a diameter large enough to swallow up Jupiter's orbit around the Sun, Betelgeuse is the closest supergiant star to Earth 640 light years away in the Orion constellation. Nearing the end of its life, it has developed a series of internal shells creating energy from the fusion of various elements, increasing its energy output to the equivalent of 120,000 Suns. The pressure of radiation pouring out from the star's interior has caused its outer layers to balloon to a vast size and cool to a deep red.

15. How are stars made?

The birth and death of a star depend on its mass. Average stars like the Sun may live for billions of years and end their lives as white dwarfs, while heavyweights live fast and die young. Ultimately, all stars scatter material across space to produce the next generation.

Nebula collapse
Star formation begins when a cloud of interstellar gas and dust begins to collapse, perhaps triggered by a supernova shockwave, or by gentler tides from passing stars.

Stellar globules
The nebula gradually separates into dense knots of matter, each a seed for a potential new star or multi-star system. Within these dark clouds, matter continues to coalesce.

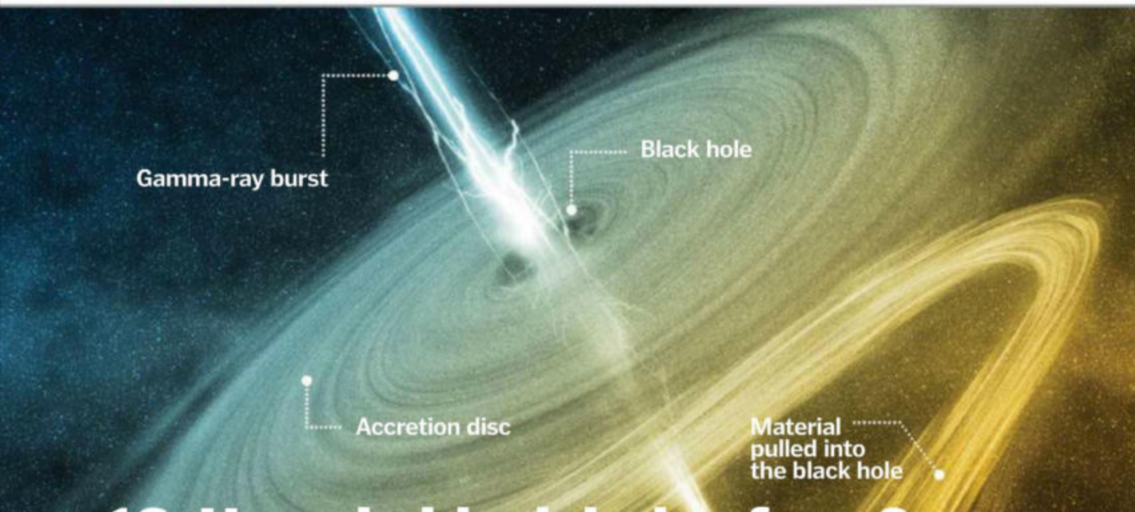
Outflow
Over time the nebula flattens into a disc with a protostar at the centre, flinging off material along its axis of rotation.

Ignition
Eventually, the protostar becomes hot and dense enough to trigger nuclear fusion within its core – a new star is born.

Planets
The material in the surrounding disc is either pulled into the star, or blown outward. The rest may coalesce to form planets.

SPEED OF THE FASTEST-MOVING STAR	**10.5mn km/h**	DIAMETER OF BETELGEUSE	**950 Suns**
ENERGY OUTPUT OF THE SUN (W)	3.8×10^{26}	LIGHT MINUTES TO THE SUN FROM EARTH	**8.3**
NEAREST STAR TO THE SUN	4.22LY		

DID YOU KNOW? *The ESA's Gaia mission, launching in 2013, will conduct a census of a thousand million stars in our galaxy*



16. How do black holes form?

When a giant star exhausts the hydrogen fuel for fusion in its core, the fusion process moves out into a spherical 'shell' while the core begins to fuse helium into heavier elements. As each fuel source in the core is spent a new shell is created, while the core moves on to fusion of ever heavier elements. Stars with eight times the Sun's mass continue the process until their cores start to fill with iron. The star cannot generate energy by fusion of iron, so when it tries, its energy supply cuts out and it collapses. The core is squashed to an incredible density, while a shockwave rebounds through the rest of the star, ripping it apart. In most cases, the star's core stabilises as a neutron star, but if the core weighs more than three to four Suns, the pressure between neutrons can't halt the collapse. The neutrons are torn apart and the core collapses to a single superdense point: a singularity. The singularity's gravity is so powerful that anything that comes too close – even light – can't escape from it. As it takes material in from its vicinity, it may briefly release a burst of highly energetic gamma rays along its axis of rotation.

17. How many stars are there in the universe?

Brace yourself for some big numbers. Astronomers believe there are probably somewhere between 10 sextillion (21 zeros) and 1 septillion (24 zeros) stars in total. That's based on recent discoveries that there are a lot more tiny, faint stars lurking in large galaxies than previously thought, and some educated guesswork on the total number of galaxies themselves.

Main sequence
Once stabilised, the star spends its life fusing hydrogen into helium, while obeying the rules of the main sequence.

Dying giant
Once its core supply of hydrogen is spent, the star must use other sources of energy to keep shining – this leads it to brighten and swell into a red giant.

Supernova
The most massive stars – at least eight times heavier than the Sun – end in enormous explosions when their energy sources are totally depleted.

Planetary nebula
Smaller red giants, on the other hand, become unstable, puffing their outer layers into the surrounding region to form a beautiful but short-lived planetary nebula.

Stellar remnants
The core of the dying star generally survives as either a slowly cooling white dwarf, a neutron star or, in the most extreme cases, a black hole.

18. If we poured a giant bucket of water on a star, could we extinguish it?

Funnily enough, it would probably have the opposite effect. The ferocity of nuclear fusion in a star depends on the temperature and pressure in its core, so if we added a huge amount of extra mass to the star in the form of all that hydrogen and oxygen, we'd increase the star's mass and central pressure, in turn making it shine brighter.

19. How do people use the stars to navigate?

Because objects in the sky stay fixed, even as Earth rotates beneath them, they form a perfect reference point for navigators. If you have an almanac and an accurate clock, you can calculate your latitude by measuring the height of a star passing across the meridian (north-south line across the sky). Similarly, you can work out latitude by comparing 'local noon', when the Sun crosses a particular meridian, with the time at a fixed location such as the Greenwich Meridian.

20. How is the distance to a star calculated?

The only way to measure a star's distance directly uses parallax – measuring the tiny difference in a star's apparent position in the sky when we look at it from different points of view (on opposite sides of Earth's orbit around the Sun). This only works for nearby stars, but, using parallax, astronomers can discover patterns in stellar behaviour from which they can work out the brightness of stars independently. They can then use this to extrapolate the distance of more remote stars.

"The WISE spacecraft itself is approximately the height and weight of a fully grown polar bear"

The WISE telescope

HIW explores this state-of-the-art infrared-wavelength space telescope

The WISE (Wide-field Infrared Survey Explorer) spacecraft houses an advanced infrared astronomical telescope and is currently in hibernation in low Earth orbit.

WISE's primary mission upon launch in 2009 was to undertake an astronomical survey of visible space (about 99 per cent) with a huge series of images in the 3, 5, 12 and 22-micrometre wavelength range bands. This was successfully completed in 2011 and the finished 'All-Sky' survey data was released to the public on 14 March 2012.

As well as successfully providing this comprehensive infrared map of visible space – a map that contains the positions of over half a billion stars, galaxies and objects – WISE has also made a number of first-time discoveries.

The WISE spacecraft itself is approximately the height and weight of a fully grown polar bear, measuring in at 2.9 metres (9.4 feet) tall, two metres (6.6 feet) wide and 1.7 metres (5.7 feet) deep. It weighs 661 kilograms (1,457 pounds). The spacecraft is split into two main sections: the instrument array and system's bus. The instrumentation side contains WISE's telescope, detectors, mirror and cryostat, while the bus – which is essentially the chassis – supports the spacecraft's computers, electronics, battery, reaction wheels, antenna and solar panel (see the 'Anatomy of WISE' diagram for more detail).

As mentioned, WISE is currently in hibernation within low Earth orbit and has been since February 2011. This is in part due to its successful mapping of the All-Sky survey, but also due to its cryo-coolant being exhausted (the frozen hydrogen used within the cryostat to keep two of its four detectors operational).

Importantly though – and the reason that the WISE craft has not been decommissioned entirely – is that the other two detectors do not require this coolant in order to function. As such, these remaining two detectors can be put to use when astronomers need to scan for near-Earth objects (NEOs), such as asteroids and comets.

Some say the WISE science instrument looks like a giant Thermos flask, while others liken it to *Star Wars*' R2-D2

The WISE telescope is prepped in a NASA cleanroom prior to launch

THE STATS
WISE IN NUMBERS

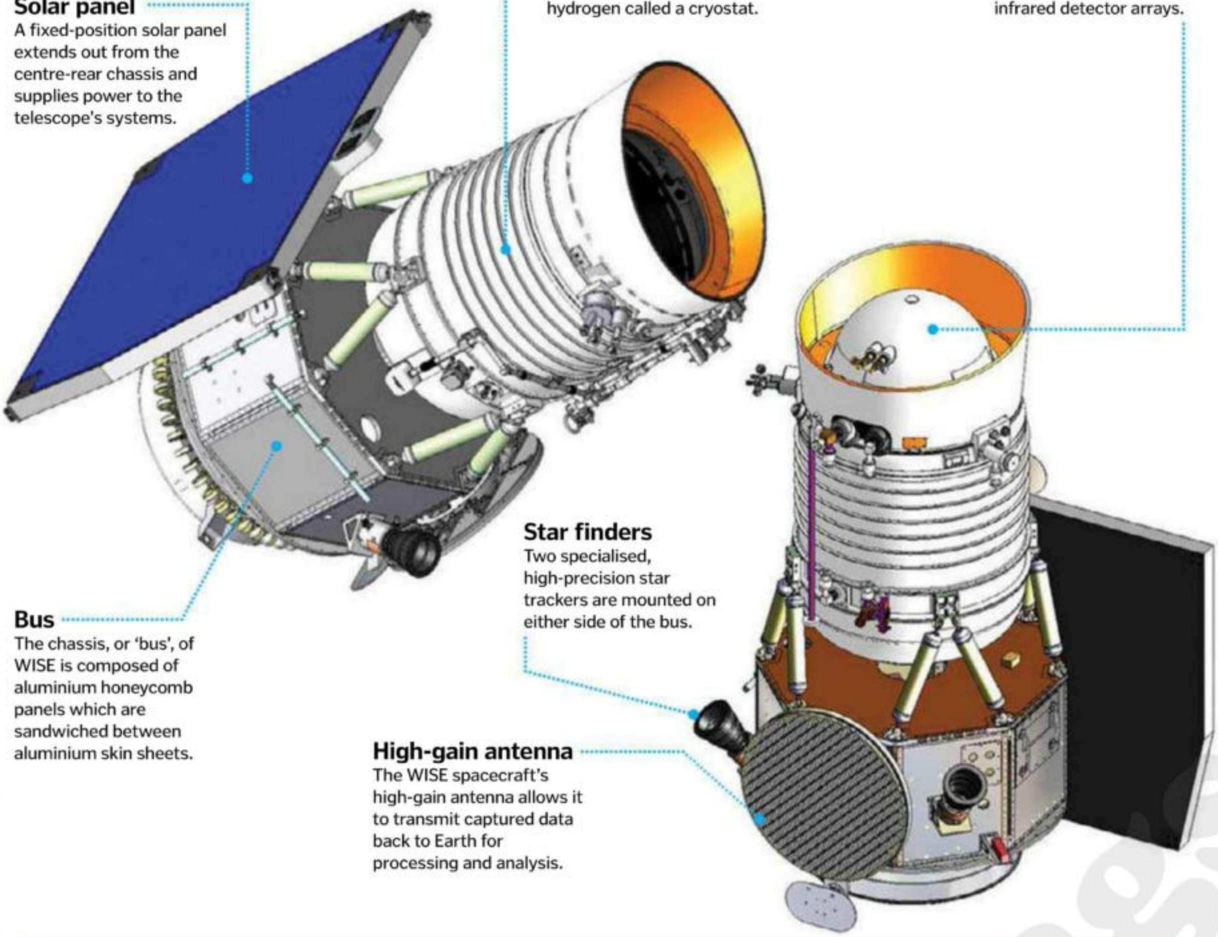
LAUNCH DATE 14/12/09 | TOTAL MASS 750kg | ORBIT HEIGHT 525km

ORBIT PERIOD 95 mins | TELESCOPE DIAMETER 40cm | POLAR INCLINATION 97.5°

DID YOU KNOW? *The telescope in the WISE spacecraft was built by L-3 SSG-Tinsley in Wilmington, MA, USA*

Anatomy of WISE

Check out the key components of this celebrated, semi-retired space telescope



Solar panel
A fixed-position solar panel extends out from the centre-rear chassis and supplies power to the telescope's systems.

Cryostat
All the instrumentation on board WISE is kept inside a cylindrical, vacuum-tight tank filled with frozen hydrogen called a cryostat.

Instrumentation
The main instrument on WISE is a 40cm (16in)-diameter telescope, along with four 1-million-pixel infrared detector arrays.

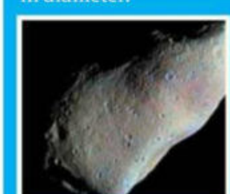
Star finders
Two specialised, high-precision star trackers are mounted on either side of the bus.

Bus
The chassis, or 'bus', of WISE is composed of aluminium honeycomb panels which are sandwiched between aluminium skin sheets.

High-gain antenna
The WISE spacecraft's high-gain antenna allows it to transmit captured data back to Earth for processing and analysis.

Five of the most important WISE discoveries

Asteroid
12/1/2010
WISE kicks off its discoveries by identifying a never-before-seen near-Earth asteroid. The asteroid – which was designated 2010 AB78 – measures approximately one kilometre (0.6 miles) in diameter.



Comet
11/2/2010
A month later WISE detects an unknown comet, which is designated P/2010 B2. The comet has an orbital period of 4.7 years, an aphelion of four astronomical units and a perihelion of 1.6 astronomical units.

Trojan
27/7/2011
Through data captured by the WISE telescope an Earth trojan asteroid is discovered. Trojans are asteroids that share an orbit with a planet near stable points in front of or behind the planet, so they can't ever collide.

Y dwarf
23/8/2011
WISE confirms the existence of a new class of brown dwarf called a Y dwarf. Y dwarfs are unique as some of them are only 300 Kelvin, which is close to room temperature (26.9 degrees Celsius/80.4 degrees Fahrenheit).

All-Sky Data
14/3/2012
The scientific community receives an atlas and catalogue of the entire infrared sky as imaged by WISE. The All-Sky Data includes more than half a billion stars, galaxies and other celestial objects that anyone can use.

"A terrestrial orbit is actually a freefall along the curve of the Earth's gravity that never touches down"

How do orbits work?

We might take it for granted, but why do stars, moons, planets or any celestial bodies constantly move around one another?

Although we don't encounter orbits day to day, it's common knowledge that in space, satellites, asteroids, moons, planets and even stars move around other celestial bodies in a seemingly perpetual dance. With the right conditions, anything will fall into orbit around Earth. But what are those conditions?

A terrestrial orbit is actually a freefall along the curve of the Earth's gravity that never touches down. The basic physics is the same for any planet or star, no matter its size. For an Earth-like planet, if an object is at the right altitude so that the thinner atmosphere doesn't drag too much – around 160 kilometres (99 miles) up – and the acceleration is enough – about 28,080 kilometres (17,450 miles) per hour – it will continue to tumble around the planet.

To put a satellite or shuttle into a circular 'high' orbit, the craft makes use of boosters to go from low orbit into a transfer orbit to achieve the required height, technically known as its apogee. Left to its own devices, the spacecraft would fall into an elliptical orbit, so an additional rocket motor called an 'apogee kick' (AKM) fires at the appropriate point. This gives the vessel the extra boost it needs to remain at that specific altitude in a high orbit.

Going in ellipses

Very few natural orbits are perfectly circular. Most follow the shape of an ellipse, or a slightly squashed circle. These elliptical orbits have a high distance (apogee) and a low distance (perigee), which occurs because the rate at which the object is falling changes. The Moon, for example, has an average orbital velocity of 3,682 kilometres (2,288 miles) per hour but speeds up as it falls towards Earth. It flies quickly through its perigee (which is approximately 360,000 kilometres/223,700 miles away), swings around the curvature of the Earth and climbs away again. It gradually slows down as it approaches its apogee (around 405,000 kilometres/250,000 miles away) until it falls back towards our planet, once again picking up speed. An equilibrium is achieved because the Moon isn't going fast enough at its apogee or slow enough at its perigee to maintain an equidistant orbit.

Learn more

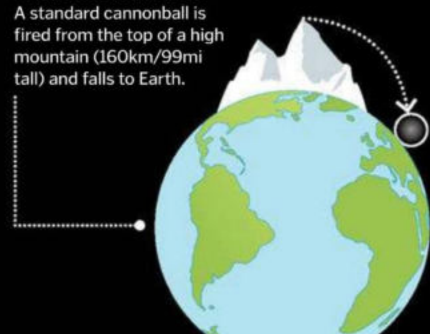
Go to **www.nasa.gov** to read more about orbits, the ISS and its path around Earth, as well as the Lunar Reconnaissance Orbiter, which goes around the Moon.

Orbit physics

Imagine an orbit as Isaac Newton envisioned it, with a cannon at the top of a mountain on Earth. The cannon is fired several times with increasing amounts of gunpowder, blasting the cannonball ever farther away…

Low acceleration

A standard cannonball is fired from the top of a high mountain (160km/99mi tall) and falls to Earth.

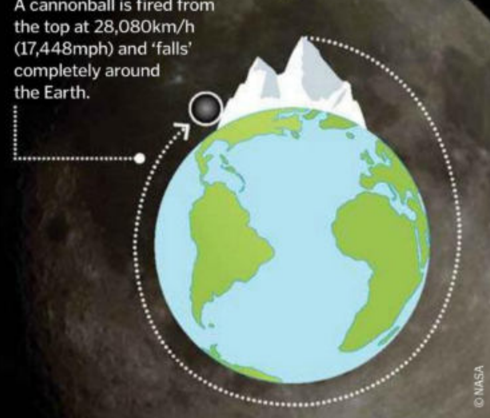


High acceleration

A very high-velocity cannonball is fired from the top and goes halfway around the world before hitting the ground.

Orbital acceleration

A cannonball is fired from the top at 28,080km/h (17,448mph) and 'falls' completely around the Earth.



"Tektites are much like obsidian glass, which is formed by terrestrial volcanic eruptions"

Exploring Eris

Get to know the biggest dwarf planet in the Solar System

When the Palomar Observatory detected Eris in October 2003, it was thought to be the long sought-after tenth planet in our Solar System. Eris has a thin methane atmosphere with a rocky surface, and a small moon, Dysnomia, which orbits it every 16 days. Eris goes round the Sun in 557 Earth years in an eccentric orbit that sometimes takes it within the orbit of Pluto.

Because Eris's orbit takes it to 5.7 billion kilometres (3.5 billion miles) from the Sun at its closest and 14.7 billion kilometres (9.1 billion miles) at its farthest, the dwarf planet's surface temperature is extremely cold, plummeting to as low as -243 degrees Celsius (-405 degrees Fahrenheit). The diameter of Eris is estimated at 2,326 kilometres (1,445 miles) making it about the same size as Pluto.

Originally classified as 2003 UB313, it was christened Eris in 2006 when the International Astronomical Union decided to designate it and the former planet Pluto as dwarf planets that are part of the Kuiper Belt of asteroids.

Dwarf planets

How does Eris stack up against other dwarf planets in our Solar System?

Eris
Eris, Makemake and Haumea, and other dwarf planets beyond Neptune are designated plutoids. It's believed up to 100 more could be out there, waiting to be discovered.

Ceres
This is the smallest dwarf planet with a diameter of just 950km (590mi). It is located in the Asteroid Belt between Mars and Jupiter and takes about 4.6 Earth years to orbit the Sun.

Pluto
The former planet has a highly inclined and eccentric orbit compared to the Solar System's eight full-scale planets. It takes Pluto 247.7 Earth years to travel round the Sun.

This Hubble Space Telescope image shows Eris at the centre and its moon Dysnomia to the lower left

What is a tektite?

Learn about these strange glass blobs that showered the Earth millions of years ago

Tektites are pebble-sized, often intricately shaped glass objects. They are much like obsidian glass, which is formed by terrestrial volcanic eruptions, except tektites have a far higher melting point and a thousand times less water content. Tektites are mainly composed of silica and contain bands of lechatelierite silica glass, which is formed naturally when lightning strikes quartz sand. Under the microscope, they display very little or no crystal structure.

The dominant theory is that they were created by meteorite/asteroid impacts several million years ago. The incredible heat and pressure generated by a huge space rock smashing into Earth would melt rocky layers and blast rubble at high velocity into the atmosphere. This would rain down over the impact site, to a distance of 6,000 kilometres (3,730 miles), as tektites. As they fell to the ground, they morphed into various shapes, like discs, dumbbells, spheres, rods and teardrops.

This theory is supported by the fact that strewn fields of tektites surrounding one impact area are distinct from the type of tektites found surrounding another impact site.

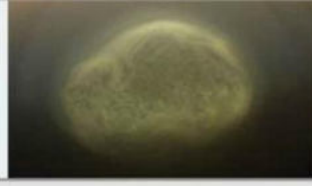
Two rocks discovered at a meteorite impact crater: the black one is a tektite, while the white one is an example of sand concretion

ON THE MAP

Tektite distribution
1 Australia
2 Indonesia, south-east Asia
3 Moldavia, eastern Europe
4 Georgia, USA
5 Ivory Coast, Africa

What permanent feature is at Titan's south pole?

A Coral reef B Hurricane C Aurora



Answer:
Titan has a perpetual hurricane at its south pole over 322km (200mi) up in its atmosphere. It's an enormous vortex where air sinks into the centre and rises at the edge, forming clouds. It's not certain how it formed as we can't see beneath it.

DID YOU KNOW? *Titan's orbital period is synchronous with its rotational period, so only one side is ever visible from Saturn*

What's beneath Titan's surface?

How did Cassini unlock the watery secrets lying below the outer crust of Saturn's largest moon?

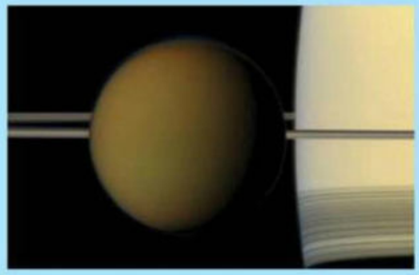
Cassini has been trying to peek below the mysterious surface of Titan for some time now, as NASA has long suspected there was more to the moon than meets the eye. In its most recent flyby, Cassini recorded the most compelling evidence yet to suggest there is a subsurface ocean.

As the moon orbited Saturn, researchers saw bulges appear on its surface as Titan was squeezed and stretched under the immense gravity of Saturn. This is a phenomenon common to all satellites including Earth, as the gravity of both the Sun and the Moon doesn't just cause the oceans to bulge by as much as 60 centimetres (23 inches), but our planet's crust too, by up to 50 centimetres (20 inches).

These are known as 'solid tides' and, if Titan were solid rock, scientists calculated that it would be bulging by up to a metre (3.3 feet). Instead, Titan's solid tides are as big as ten metres (33 feet) in height, indicating there is an ocean beneath its surface. Using data from five previous flybys, NASA was able to calculate Titan's internal structure layer by layer, including a global body of water between its silicate core and its solid surface.

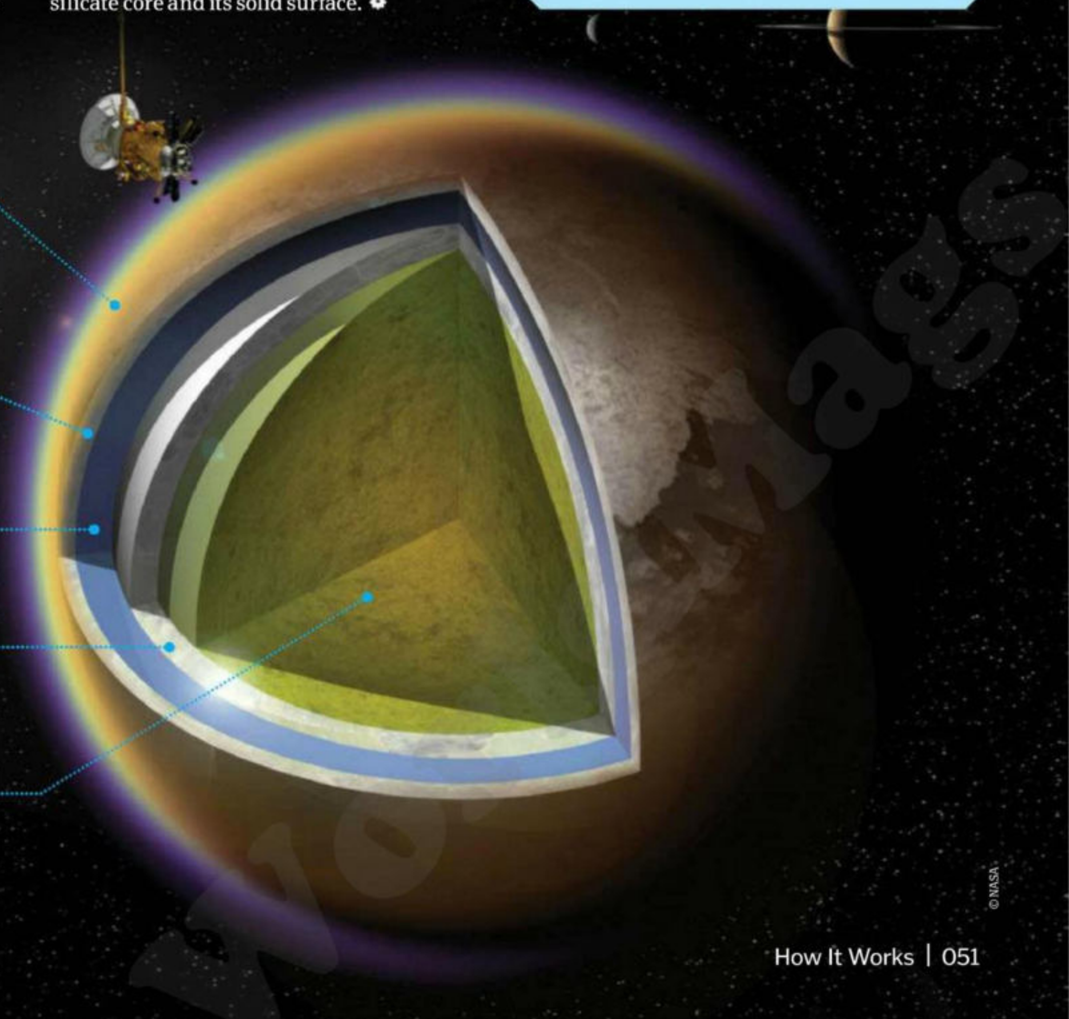
Why Titan's unique

So what if there's water on Titan, a moon that's over 1.5 billion kilometres (932 million miles) from Earth? We're searching for the presence of water on Mars because there it's in contact with rock, but on Titan scientists aren't sure whether the bottom of this ocean is rock or ice. Instead, NASA is interested in the presence of methane and the effect of a liquid water ocean on methane escaping to the surface. According to the Cassini team, the abundance of methane on Titan is what makes everything that is unique about this moon. Yet we don't fully understand how the methane gets to the surface in sufficient quantities, because once there it dissipates in a relatively short time. A subsurface ocean of liquid water would act as a reservoir for methane and would also free gas from the ice.



Inside Titan

Explore the composition of this complex moon, from the core to the atmosphere



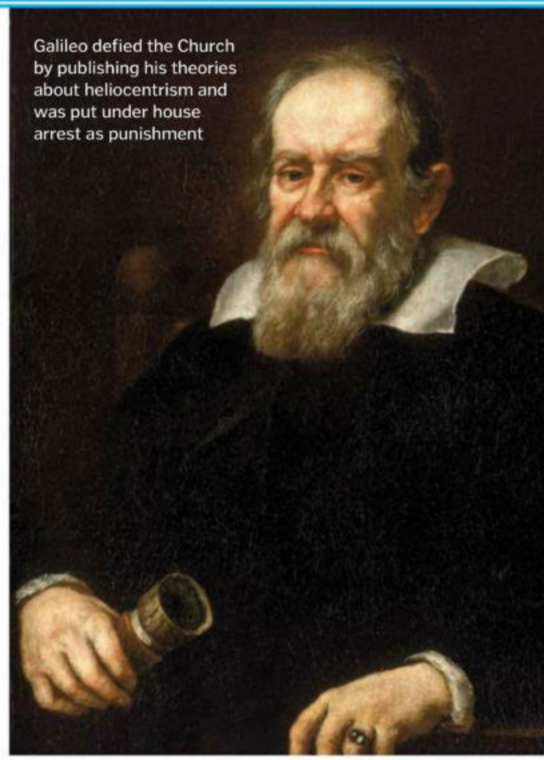
Organic-rich atmosphere
The atmosphere is mostly nitrogen (98 per cent). The remainder largely consists of methane and hydrogen.

Water ice shell
Titan's surface is geographically young, featuring hydrocarbon seas – lakes and oceans of liquid methane.

Subsurface ocean
Less than 100km (62mi) beneath the surface is a shallow ocean of liquid water and ammonia.

High-pressure ice shell
A layer of extremely cold crystalline water ice under immense pressure surrounds the core.

Hydrous silicate core
It's suspected that Titan has a rocky 2,000km (1,242mi)-radius core enriched in hydrated silicates.



Galileo defied the Church by publishing his theories about heliocentrism and was put under house arrest as punishment

Galileo Galilei

The father of modern science and one of history's most influential figures, today's astronomers owe Galileo a great debt

Had you been alive in the late-16th and early-17th centuries, Galileo would have challenged, if not changed, the way you looked at the world. His studies into the laws that govern motion, strength of materials and the very nature of scientific method of the time paved the way for scientific advances for the next few centuries. Though the achievement he's best known for was to advocate the heliocentric system, he was such a staunch proponent of this in the face of punitive opposition that the scientific community was forced to re-examine its beliefs.

The world that Galileo was born into in 1564 was as much a boon to his career as a hindrance. On the one hand, contemporary Renaissance-era geniuses like Nicolaus Copernicus and Leonardo da Vinci had already proved the transition between the expanding definitions of the sciences. Italy was a thriving hub for artists, explorers, mathematicians, writers, inventors and more; ideas disseminated with unprecedented freedom and new concepts bubbled up from archaic beliefs, rocking theories of the time that had gone unchallenged for hundreds of years.

On the other hand, Galileo was a tenacious antagonist who lived in Pisa, Italy, at a time when Rome's political power was still very strong and religious censorship was rife. His feud with the Vatican dictated the last few decades of his life, perhaps ending Galileo's run of stellar discoveries prematurely.

In 1588, at the age of 24, he was already a mathematician of some renown in Italy, having circulated his theories on weight and the centre of gravity while lecturing to the prestigious Florentine Academy. It brought him to the attention of the University of Pisa in 1589, which appointed him the chair of mathematics. It was here that he performed his experiment from the top of the Leaning Tower of Pisa, dropping various weights to the ground and proving that the speed of an object's fall is not proportional to its weight. The backlash against his attack on Aristotle's theories saw him released from his position in 1592, although he immediately moved on to greener pastures as chair of mathematics for the University of Padua – part of the Venetian Republic. During his time here he would make several contributions to science that would revolutionise astronomy.

Galileo has been so frequently associated with the telescope that he's commonly credited with its invention, which isn't true. The telescope was actually invented in the Netherlands in 1608, proving a watershed for both Galileo's career and science. He saw how to drastically increase the magnification of the telescope through lens grinding and, in August 1609, he presented his improved design to the Venetian Senate. They were so impressed with his re-invention that they immediately doubled his salary and extended his tenure of the chair of mathematics to a lifetime one. This invention was also the tool with which Galileo would achieve his magnum opus.

"They were so impressed with his re-invention that they immediately doubled his salary and extended his tenure of the chair of mathematics to a lifetime one"

The big idea

In 1592 Galileo invented an air thermometer, or thermoscope. His theory was that changes in heat levels would be shown by liquid, rising or falling in a tube, though the notion of temperature itself didn't exist then. The Galileo thermometer was invented long after this by the Accademia del Cimento in Florence and named in his honour, using the principles laid down by Galileo to create a sealed glass cylinder containing a clear liquid (eg water) and floats. These floats had different densities and would bob to the top at varying temperatures – modern Galileo thermometers often have tags on the floats too.

A life's work

A brief look at some of Galileo's key achievements throughout his lifetime

1564 Born 15 February in Pisa, Italy, a city he would return to later in life.

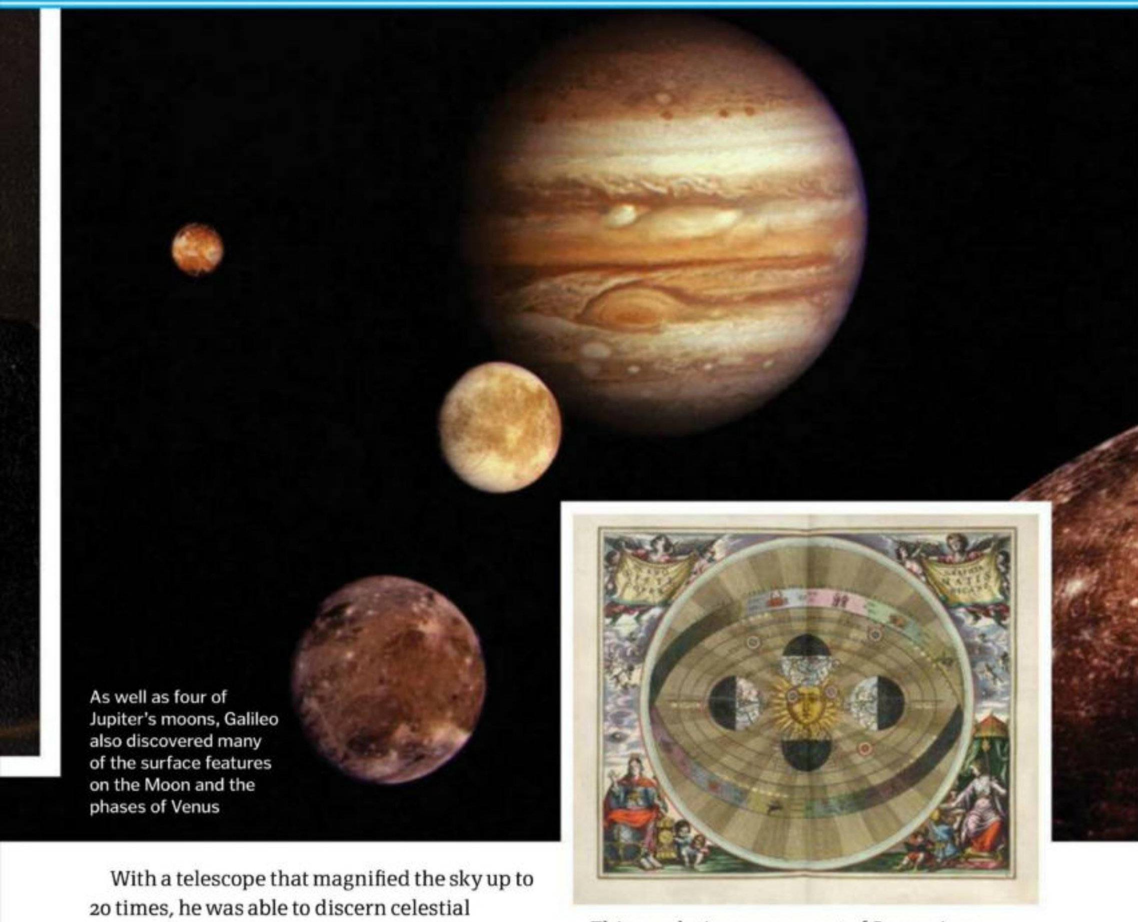
1581 Enrols at the University of Pisa to study medicine, but later decides to study mathematics and philosophy.

1588 Applies for the chair of mathematics at the University of Bologna but doesn't get it.

1592 Galileo's patrons secure him the chair of mathematics at the University of Padua.

1609 Continues research on motion and determines the law of falling bodies after an experiment from the Leaning Tower of Pisa.

1609 Reinvents the telescope and receives substantial financial reward from the Venetian Senate.



As well as four of Jupiter's moons, Galileo also discovered many of the surface features on the Moon and the phases of Venus

With a telescope that magnified the sky up to 20 times, he was able to discern celestial objects in unprecedented detail, like the Moon, whose surface he discovered was pocked by craters and not perfectly smooth. He was also able to make out four satellites orbiting Jupiter. This flew in the face of the contemporary Aristotelian thinking at the time: that the Earth was an imperfect and corrupt celestial body surrounded by the immutable heavens. The Moon and the planets in fact revolved around the Sun, which was the centre of the known universe and there was more than one centre of motion within this universe.

This revolutionary support of Copernican heliocentrism saw Galileo fall out of favour with the Vatican. After facing an inquisition in Rome, he was sentenced to lifetime house arrest – a relatively lenient punishment at a time when heresy was usually met with torture, prison or death. Galileo continued his work in secrecy and even managed to smuggle a vitally important book summarising his research into motion – **Dialogues Concerning Two New Sciences** – out of Italy and published in the Netherlands, before he died in 1642.

In their footsteps...

Sir Isaac Newton

Newton was born the same year that Galileo died. As a physicist, mathematician and astronomer (among other things) who lived in the same century, he was greatly influenced by Galileo's work. Using Galileo's own work on laws of motion and gravity (as well as Kepler's laws of planetary motion) he removed any doubt over heliocentrism. He also built on Galileo's own telescope design.

Benedetto Castelli

As a student of Galileo, Antonio Castelli (later to be known as Benedetto) helped with Galileo's study of sunspots, in his examination of heliocentrism and Copernican theories. When Galileo left his position as chair of mathematics at the University of Pisa, Castelli took the role. For his part in the scientific revolution, Castelli published several important works on running water.

Top 5 facts: Galileo

1 The heretic
Much of Galileo's work was withdrawn and banned during the 17th century by order of the Church. It wasn't until 1718 that reprinting was allowed again.

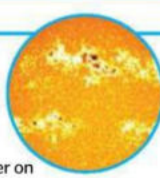
2 More inventions
In addition to the objective lens and thermoscope, Galileo also invented a geometric compass, a microscope, a pendulum clock and contributed greatly to many other technologies too.

3 Blindness
In 1638 – towards the end of his life – Galileo went blind. Yet even in his final few years he continued with his work, taking on an apprentice to help him who was with Galileo until his death.

4 Not always right
Sometimes Galileo was far from being correct. For example, he disagreed with Kepler's theory that the Moon caused the Earth's tides and believed that they were down to the rotation of the Earth and orbit of the Sun.

5 Jupiter's moons
Galileo discovered the Jovian moons Io, Callisto, Ganymede and Europa, naming them the Sidera Medicea (Medicean stars) after his patron Cosimo II de' Medici. They were later renamed the Galilean moons.

1610
Makes one of his most famous discoveries – what are now known as the Galilean moons of Jupiter.



1613
Publishes a paper on sunspots, called *History And Demonstrations Concerning Sunspots And Their Properties.*

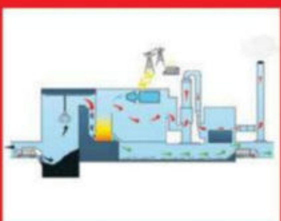
1623
Il Saggiatore (The Assayer) – Galileo's views on physical reality and the scientific revolution – is published.

1632
Publishes his controversial *Dialogue Concerning The Two Chief World Systems*, falling foul of the Church.

1633
After a commission to examine Galileo's work, he is charged with heresy and sentenced to life under house arrest.

1642
In his final years, Galileo summarises his life's work and teaches a student, before he dies.

The internet has totally revolutionised the way we live, work and play, but what tech lies behind this global network? Also, we take apart Apple's latest iPhone, look at how handwriting-recognition apps digitise text and explain why acoustics in the Sydney Opera House are pitch-perfect.



60 **Energy from waste**

63 **Sydney Opera House**

64 **iPhone 5**

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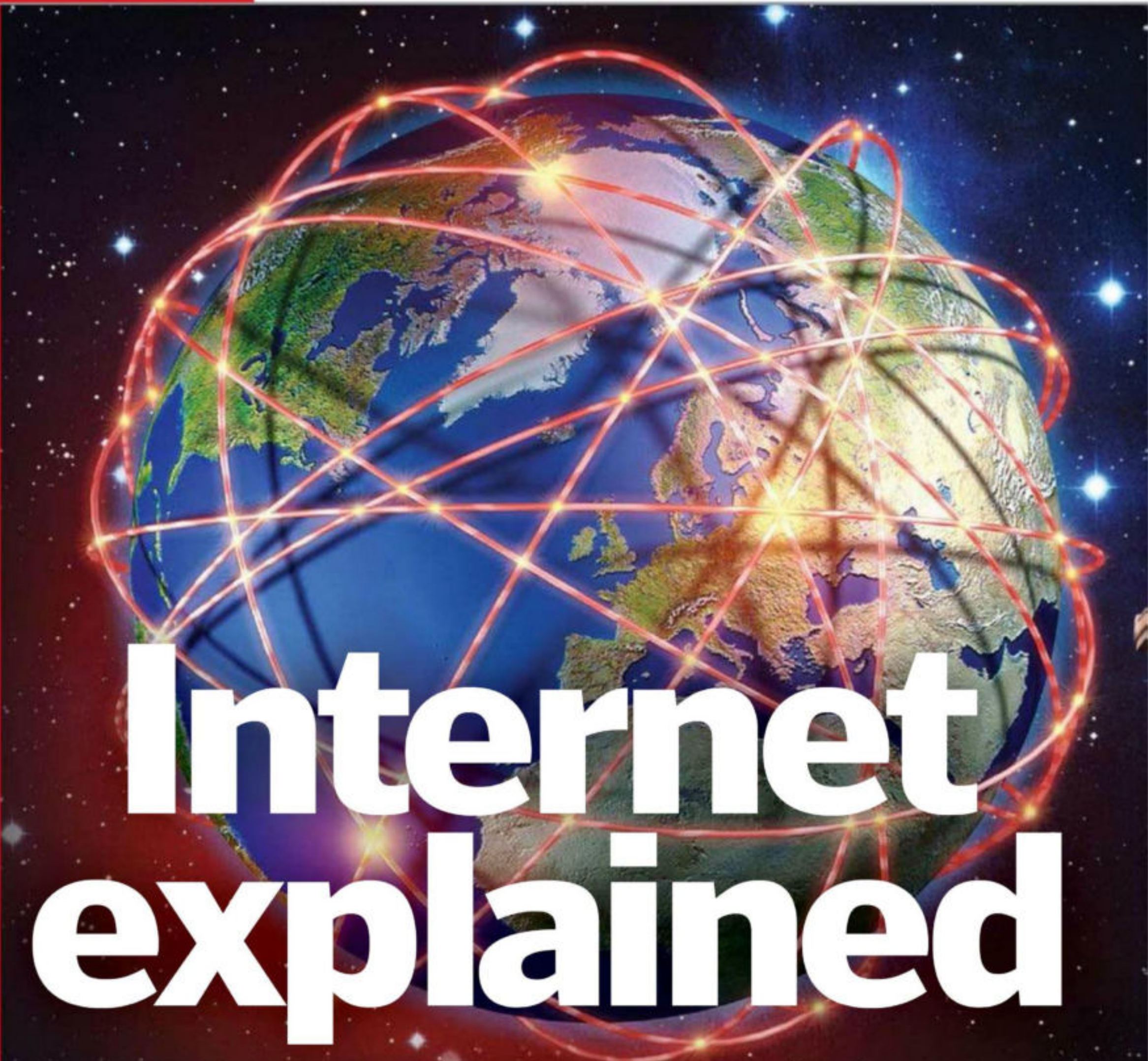


Internet explained

It takes more than just cables to connect over 2 billion people and six continents

22 years ago, you had never looked at a single webpage, 15 years ago you hadn't searched on Google. Just eight years ago you had yet to see a YouTube video. All these things are now as much a part of our lives as television, and much more relevant to most of us than newspapers. The internet has the ability to subvert national laws, overthrow governments, search for extra-terrestrial life – and even find us a husband or wife.

But what actually **is** the internet? Like gravity, it's so ubiquitous we mostly just think of it as a sort of magic glue that binds us. The server that hosts **www.howitworksdaily.com** isn't strictly **part of** the internet, it's **connected to** the internet. The internet itself is the collection of links that join the smaller networks run by companies, governments and other organisations. It's a network of networks.

When you type **www.apple.com** into your browser address bar, the request for that webpage travels from your computer to your broadband router by Wi-Fi radio signals, but after that, its journey is constrained by wires. First it travels through ordinary telephone wires to your local telephone exchange. Then it gets routed through higher-capacity lines that connect to your Internet Service Provider (ISP). For convenience, these cables follow the same route as the voice telephone lines and share the same trenches in the ground, but they are dedicated data cables that only carry digital internet traffic. Your ISP has leased capacity on even bigger fibre-optic cables that forward your

KEY DATES
INTERNET HISTORY

1969 ARPANET, precursor to the internet, is created. The first message was the L and O of 'login'.

:-)

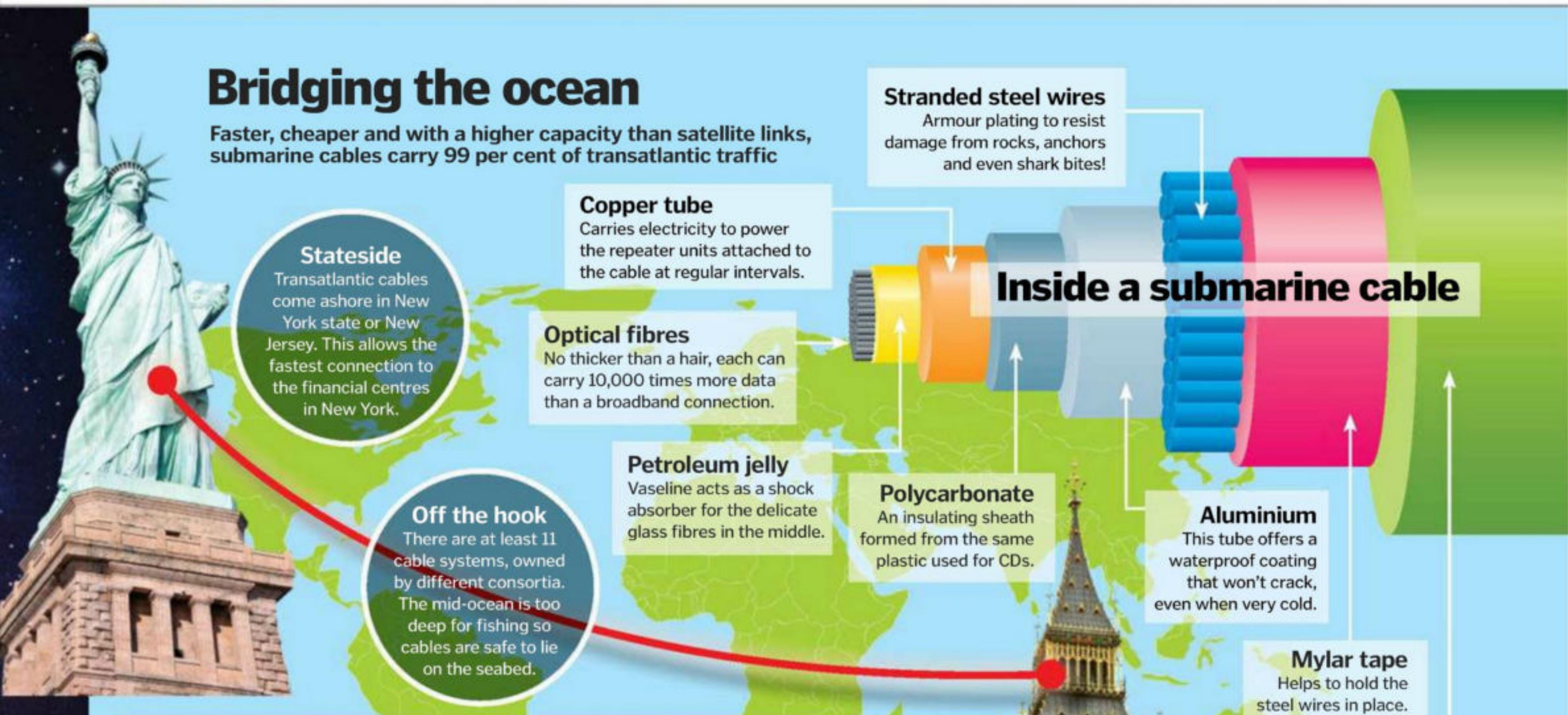
1982 The 'smiley' emoticon (left) is invented in 1982, by a professor at Carnegie Mellon University, PA, USA.

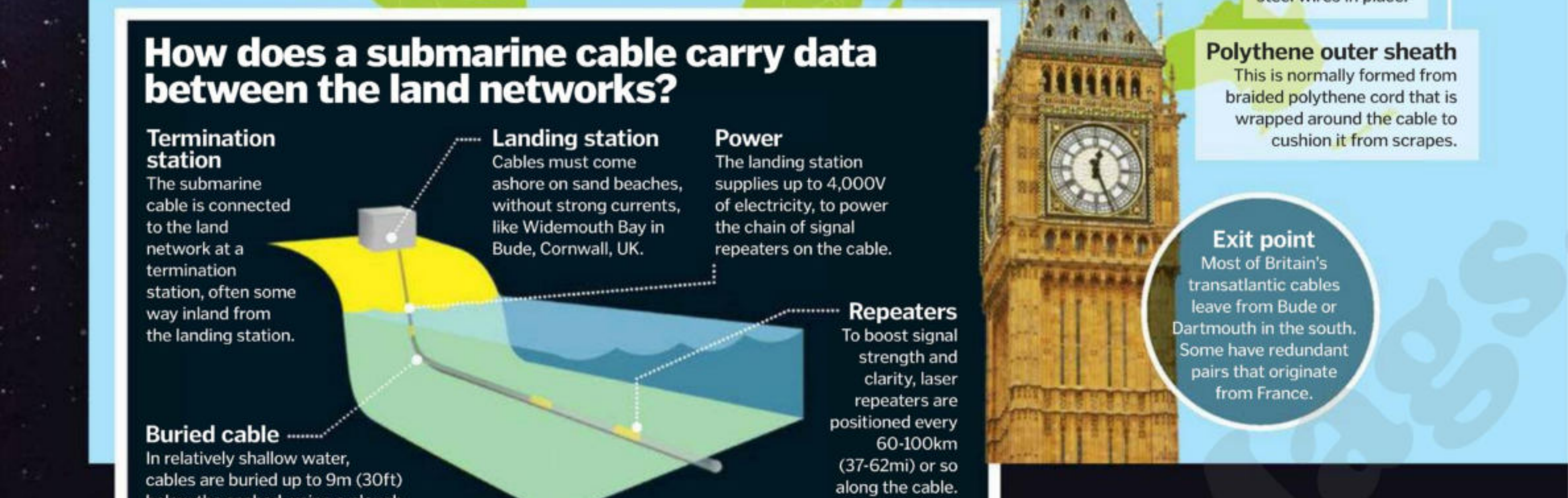
1985 The first .com domain name is registered. It was **symbolics.com** and belonged to a Massachusetts computer firm.

1996 Hotmail launches the first free web-based email service. Microsoft buys it for $400m the following year.

2004 Mark Zuckerberg launches Facebook, which hugely popularises social networking.

DID YOU KNOW? *The first webcam was set up in 1991 in a lab at Cambridge University. It showed a coffee pot*





data to one of the major internet exchanges, such as the London Internet Exchange (LINX). This is a collection of ten buildings, in and around the Greenwich area, that are all joined together by multiple ten-gigabit fibre-optic lines. LINX is a non-profit switching centre whose running costs are shared by lots of ISPs to route traffic all over the planet.

To get to America, your webpage request must cross the Atlantic via a submarine cable. There are 11 main cable systems, leaving from either Devon/Cornwall, Ireland or France. Your data is passed to one of these by LINX, passing through a shorter submarine link under the English Channel or the Irish Sea, if necessary. The 5,650-kilometre (3,500-mile) journey over the pond takes less than 100 milliseconds.

Back on land, more high-speed cables (sometimes called the internet 'backbone') take your request to a data centre. These are warehouses the size of shopping malls containing hundreds of rows of server cabinets. Apple has one of its main data centres in Maiden, North Carolina. The advantage of siting it there is because a data centre needs three things in large amounts: space, electricity and cooling. Cooler locations like North Carolina save a lot of power by using the natural cold air instead of air conditioning. Even so the electricity demands of all those servers is enormous. Over 1.8 trillion gigabytes was added to global data centre storage capacity in 2011 and all that data needs power to keep it accessible. Most data centre servers spend a lot of time idling, but extra capacity is needed to cope with sudden spikes in demand.

When your website request finally arrives at one of Apple's servers, the data for the front page is assembled, split into 'packets', each with the internet address of your home computer and then sent back the way it came. This happens every time you click a link.

"The internet itself is the collection of links that join the smaller networks run by organisations"

The internet in numbers

...from the fastest broadband to how many tweets we post each day

How long are we online?

How many hours do Britons spend online compared with the rest of the world?

Global rank	Country	Hours/month
1	Canada	43.5
2	USA	35.3
3	UK	32.3
5	France	26.6
11	India	11.9

WWW

620 million

Number of websites worldwide

233 million

Total domains worldwide

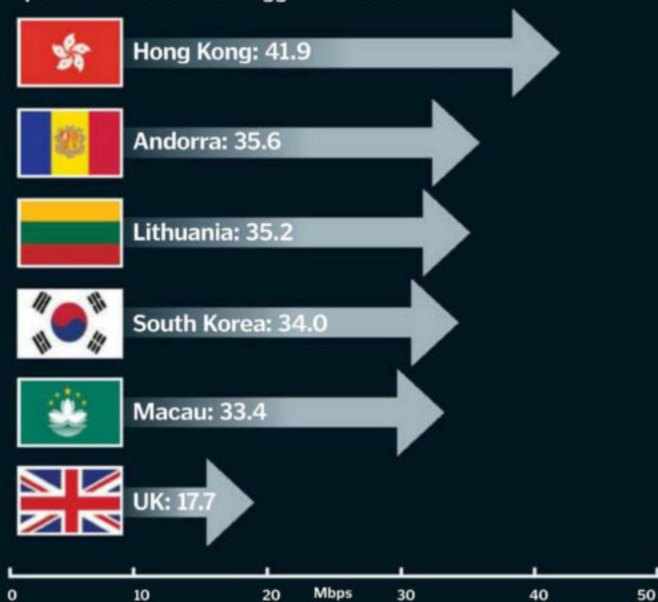
294 billion

emails are sent each day worldwide

...compared with an estimated 3.5 billion physical letters and parcels

Who has the fastest broadband?

It may come as a surprise, but the fastest download speeds aren't from the biggest countries



1.63 billion GB

Data sent around the internet every day

This is equivalent to 347 million DVDs

250 million

tweets are sent every day

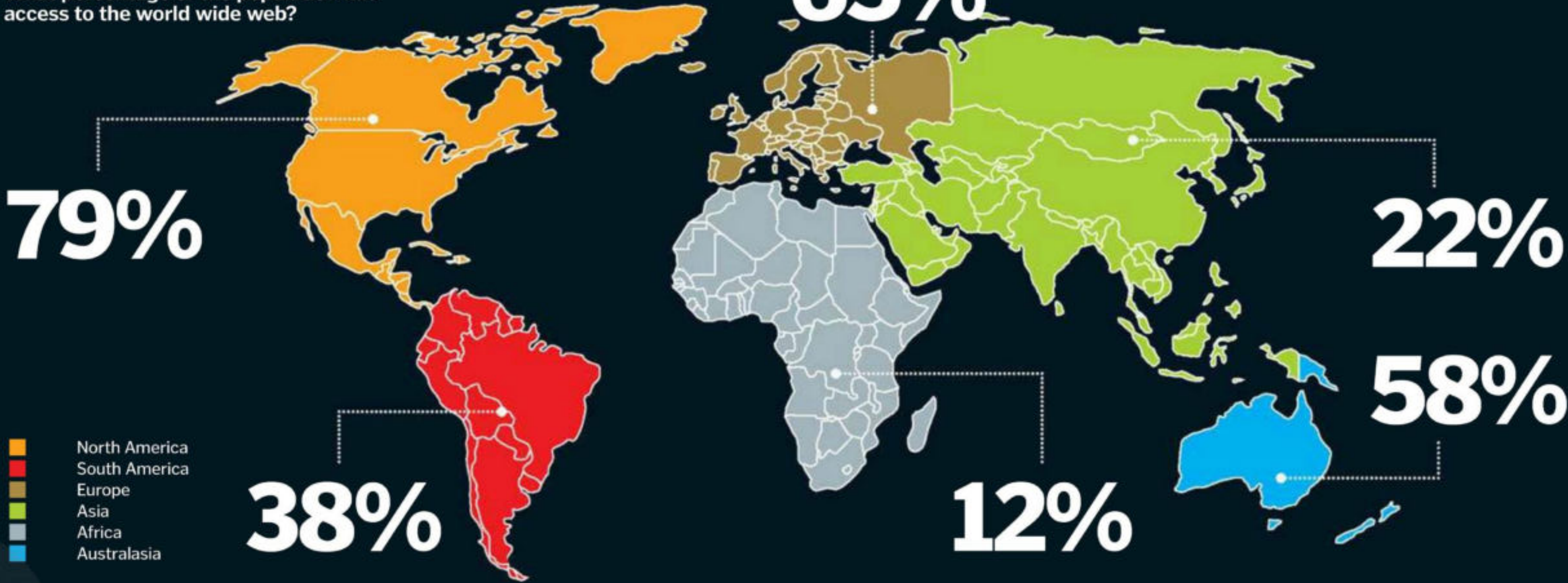
72 hours

of video is uploaded to YouTube every minute

DID YOU KNOW? Discover Magazine suggested the net weight of all data on the internet is about the same as a grain of sand

Connected continents

What percentage of the population has access to the world wide web?



Focus on social networks

Whether it's viral videos or pictures of our lunch, we're addicted to sharing

56%
of users admit to spying on their partners through social networks

7hrs 46m
Ave time a user spends on Facebook per month

Brazilians have the most online friends – an average of 481 per user

What are we surfing on?

What percentage of UK adults connect to the internet on each device?

Tablet computer (eg iPad): 6%

Portable media player (eg iPod): 8%

Games console (eg Xbox Live): 11%

Mobile phone: 45%

PC or laptop: 72%

Online activity breakdown

Discover how much time people dedicate to a range of tasks from shopping to emails

Social networking	22%
Searching	21%
Reading	20%
Emails/communication	19%
Multimedia	13%
Shopping	5%

> "If your video-conference hits a slow patch, it's better if the network discards any late packets"

The software of the internet

The internet is made of protocols… but what is a protocol?

The internet is like a road network. It consists of the tarmac and the junctions and the vehicles that use them. It also comprises the rules that govern how cars should travel. Rules like 'Stop when the light is red' are every bit as vital to the functioning of the internet as a real road system.

The main protocol is called simply Internet Protocol (IP). It defines the way data is broken into chunks, or packets, and each packet has the destination address marked separately on it. This means that if the stream of data gets interrupted en route – perhaps because one server gets too busy – the packets can be diverted to alternative links without losing their way. The packets are also numbered, so that the data can be reassembled in the correct order.

This fault tolerance works fine for most kinds of data. Webpages are fairly small, so you can wait for a second or two while the packets all arrive, and with video you can buffer a few seconds' worth to smooth out any hiccups in delivery. But games and video chat need a real-time exchange. They use a stripped-down version of the IP packet, called UDP (Universal Datagram Protocol) that misses out some of the fault-tolerant features of IP. If your video-conference hits a slow patch, it's actually better if the network discards any late packets and lets the image break up a bit, rather than stalling the whole conversation.

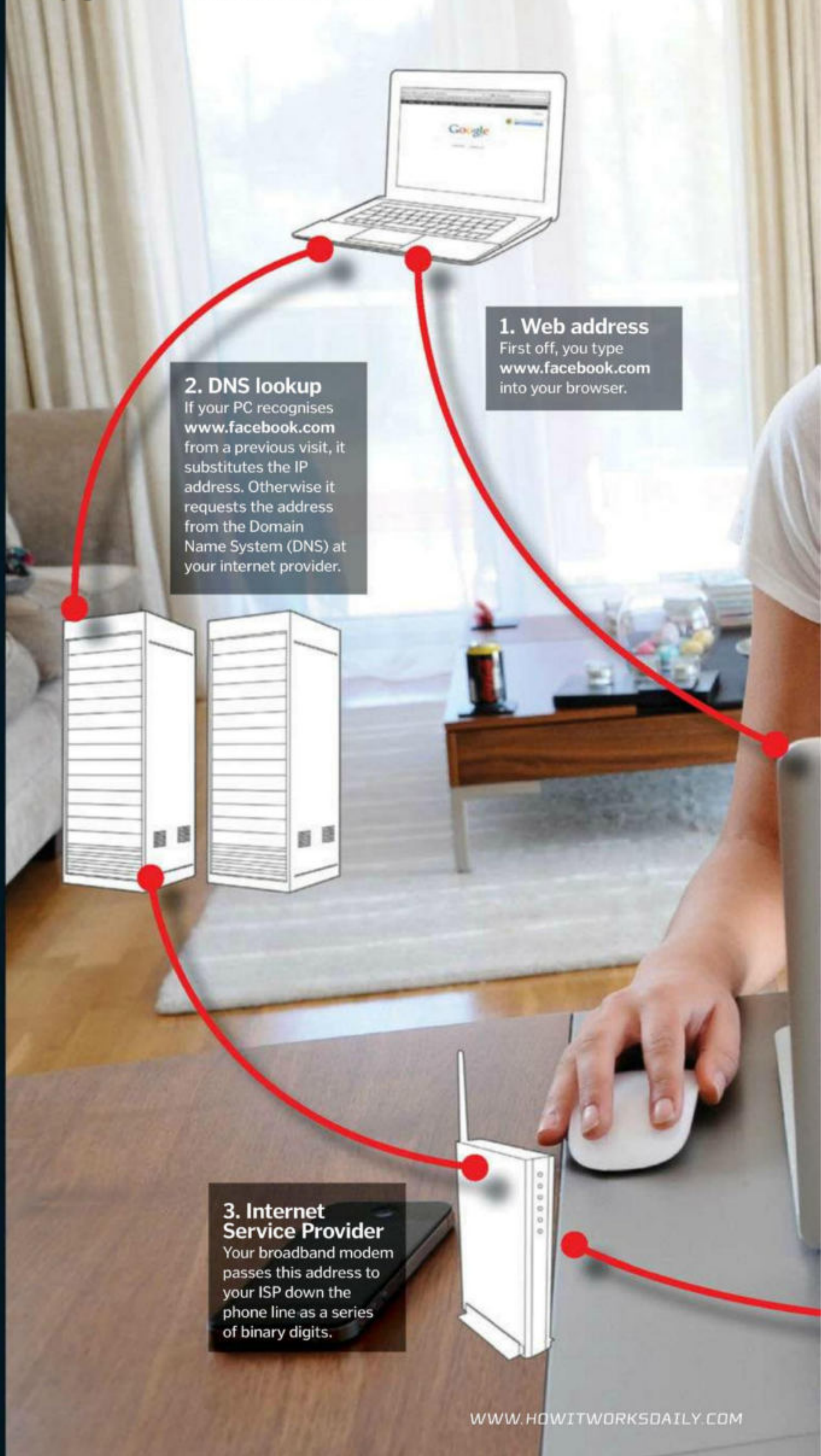
ISPs also prioritise some kinds of data over others. This is called traffic shaping and it enables them to ensure that time-sensitive data, such as video, doesn't get interrupted unnecessarily. Traffic shaping has a commercial side too. For instance, ISPs regularly prioritise web and email traffic for business customers over domestic online gaming.

An IP address is a sequence of four numbers – 65.55.58.201 is one of Microsoft's servers, for example. But number sequences are hard for humans to remember, so a separate Domain Name System (DNS) acts as an alias for all the IP addresses. When you register **myfirstdomainname.com**, an entry is made in a database that assigns an IP address to that domain name, so no one else can use it.

The original world wide web, designed by Tim Berners-Lee, used very simple webpages described by HyperText Markup Language (HTML). This leaves almost all decisions about layout and font to the web browser on your computer. Modern web designers want a lot more control over the layout so webpages nowadays don't use as much HTML. Instead, programming languages like Java create animated and interactive elements and the content is often generated dynamically by a database. This is what allows Gmail to show a personalised email inbox, for example.

The internet at work

How does your computer connect to a webpage on the other side of the world?



5 TOP FACTS
INTERNET MYTHS

Nuclear attack proof
1 The internet protocol was designed to be highly fault tolerant. But that's because early network hardware was very unreliable – not because of the threat of nuclear war.

Berners-Lee made links
2 He invented the world wide web and the first browser program, but the hyperlink was invented by Ted Nelson as part of Project Xanadu at Harvard, 30 years earlier.

Social networks are new
3 In the Eighties, CompuServe, FidoNet and CIX bulletin board systems already allowed users on dial-up modems to chat online, leave messages and contribute to discussions.

Addresses are scarce
4 The IPv4 protocol only allows 4 billion unique addresses, but IPv6 is already rolling out and this will provide 10,000 trillion trillion addresses for every person on Earth!

The internet is free
5 It isn't and never has been. The internet is a very expensive collection of hardware paid for by governments, corporations and, ultimately, all of us.

DID YOU KNOW? *The first ever web address didn't begin with www but the slightly less catchy nxoc01.cern.ch*

The internet is *not* the web

The web is a collection of webpages, hosted on servers around the world and connected by links. The web uses the internet to transfer data between you and those servers, but it's just one of many services using the internet. Email is another one, so are the iTunes Music Store and the online game *World Of Warcraft*. The world wide web has only existed since 1991, but the internet was connecting universities, libraries and governments for 20 years before that. It's like saying a coach company, like Greyhound, is the same thing as the motorway.

The future?

The internet began as an academic network funded by the US Department of Defense. Today it is a transnational entity that consistently resists attempts to regulate or police it. Censorship and libel laws are circumvented with the same efficiency that allows internet traffic to reroute around physical damage to the network. The internet has jumped from the mainframe computer to the home PC, to the wireless laptop and then to the truly mobile smartphone. Google is already trialling the next major leap with Project Glass, which is a voice-controlled, internet-connected pair of glasses that projects information directly onto your retinas. Smaller, more mobile internet access devices could spell the end of the browser as our gateway to the internet. Indeed, webpages might be replaced by specialised apps that provide their own ways to share information; Facebook and Twitter already do this. Augmented reality, where information is overlaid on camera images and real-time maps, means that the internet is no longer just a place we visit. It's actually where we live.

"Direct combustion plants work by burning waste in a huge furnace to generate high-pressure steam"

Waste-to-energy plants

Converting refuse into electricity, WTE plants are a power source of the future

Waste-to-energy (WTE) plants are a widespread type of refuse recycling facility. They specialise in processing non-recyclable materials through one of three different methods: direct combustion, pyrolysis or gasification.

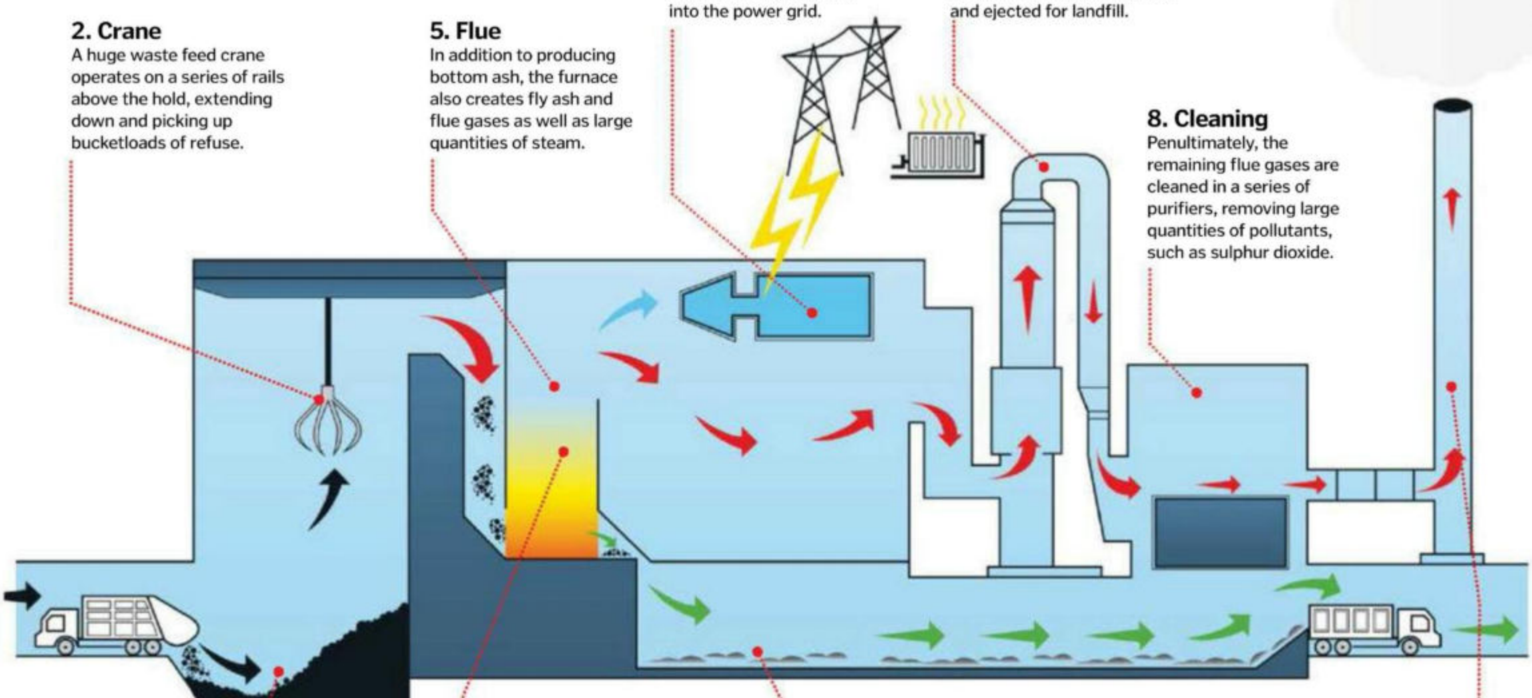
Direct combustion facilities are the most common. These WTE plants work by burning waste in a huge furnace to generate high-pressure steam, as well as a number of reusable by-products (bottom ash, for example). The steam is useful as, once created by the combustion unit, it can be redirected to a steam turbine – this in turn can generate electricity. The electric power it produces can then be fed directly back into the power grid.

The second variety of WTE plant employs the process of pyrolysis. This type of facility thermally degrades waste in an oxygen-free conversion unit, breaking down material and producing syngas (synthesis gas), which is a mixture of carbon monoxide and hydrogen that can later be turned into diesel, methane, methanol and dimethyl ether. All of these materials can be reused as forms of energy, most notably in combustion engines.

The final type of WTE facility is the gasification variety. These plants specialise in a process that converts organic and fossil-based carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide. While slightly more complicated, gasification plants have the advantage of being able to generate electricity in engines rather than steam turbines and also a simplified filtering process compared to direct combustion (explained below).

Rubbish electricity

Learn how direct combustion WTE facilities generate electricity from just our refuse



DID YOU KNOW? *Many ancient documents are being preserved for the future using HWR technology*

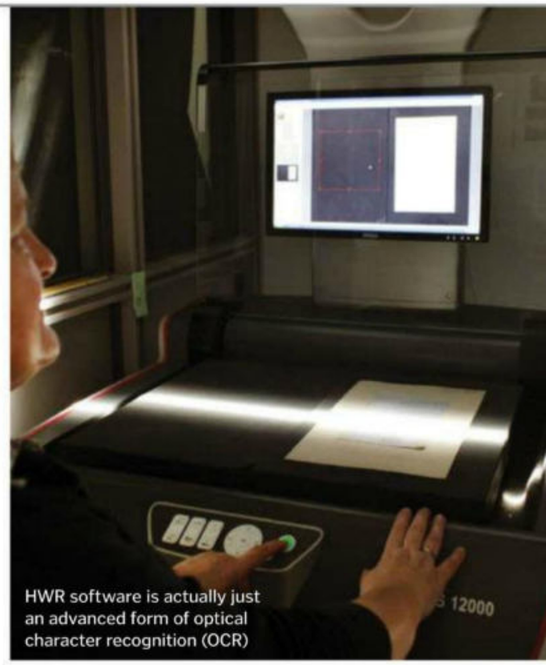
Handwriting-recognition tech

A closer look at the clever software which can decipher human writing and then digitise it

The ability for a piece of software to recognise handwriting is a natural extension of an older concept: optical character recognition (OCR). This was conceived around a century ago, when a machine was developed to aid telegraphy that read characters and translated them into code.

Conceptually, modern handwriting recognition (HWR) performs the same conversion, but with an additional process. The printed or handwritten document is first scanned, or written onto a touchscreen mobile or tablet device. The HWR app then separates each character and – using a pre-programmed bank of algorithms – matches it to what it thinks is the most likely letter on a database. Modern HWR software uses context to help decide one letter from the next and some programs can even 'learn' from reading a user's writing over time, increasing efficiency.

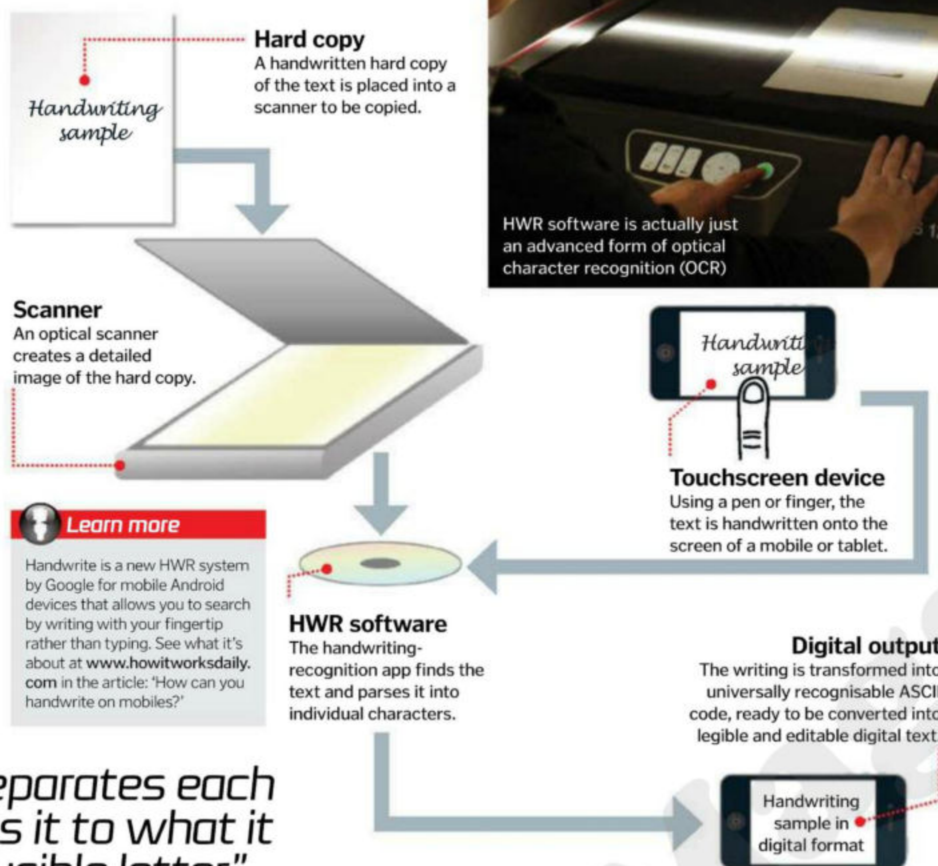
Finally, the software creates a digital output, which can be read by any device and then replicated as editable text.



HWR software is actually just an advanced form of optical character recognition (OCR)

HWR in action

We break down the process of converting handwritten text into a digital format



Learn more

Handwrite is a new HWR system by Google for mobile Android devices that allows you to search by writing with your fingertip rather than typing. See what it's about at **www.howitworksdaily.com** in the article: 'How can you handwrite on mobiles?'

> "A piece of software separates each character and matches it to what it thinks is the most plausible letter"

© Corbis

KEY DATES
OPERA HOUSE

1959
After the demolition of the Fort Macquarie Tram Depot in 1958, construction work begins.

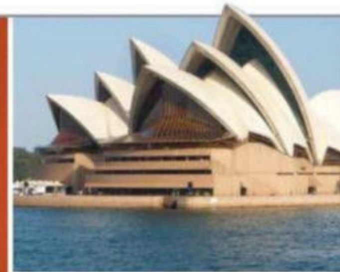
1973
The Sydney Opera House is completed ten years late and seven times over the original budget.

1999
The Sydney Opera House Trust reconciles with estranged architect Jørn Utzon, who quit in 1966.

2004
Utzon begins planned renovation work. A room is redesigned and dedicated to him (right).

2009
Utzon's son Jan helps redesign the Western Foyers, adding new ticket booths, shops and toilets.

DID YOU KNOW? The Sydney Opera House features a grand organ with a staggering 10,500 pipes!



Sydney Opera House acoustics explained

How does the Concert Hall inside this famous landmark disperse sound so well?

The Sydney Opera House's Concert Hall still remains one of the premiere destinations for concerts and recitals in the world, thanks in the main to its great acoustics.

The Concert Hall has a very distinctive geometric design. Similar to a cathedral, the auditorium has an incredibly high vaulted ceiling, a long, stepped main seating array, raised organ platform, recessed sound stage, plus an elevated, staggered gallery. This layout, especially aided by the high ceiling, grants sound within the hall a bright quality with strong reverberation; with a full audience the reverberation time is approximately 2.2 seconds from 100 to 8,000 Hertz.

Complementing the geometric layout are the hall's construction materials, which – ranging from the smallest to the largest aspect – were picked specifically to improve sound quality and dispersal. The walls and floors are made of laminated Australian brush box, the ceiling from white birch, while much of the ceiling's crown is crafted from sculpted plywood. The extensive use of wood offers excellent control of reverberation and echo as well as generating a softer reproduction of sounds. In addition, each chair is made from white birch and lined with wool, the latter material providing excellent noise absorption at the critical point of contact.

Finally, the hall sports a unique feature: a fully height-adjustable canopy directly above the sound stage. This canopy comprises 18 doughnut-shaped acrylic rings that extend down from the ceiling and redirect sound waves that emanate directly up from the stage to other more beneficial areas of the room. This helps with the hall's lack of early sound wave reflections due to its height, and also maintains the auditorium's geometry.

Key acoustic features

We explore the Sydney Opera House's Concert Hall to see how sound travels to every corner

Clouds
18 doughnut-shaped acrylic rings, or 'clouds', hang above the sound stage. These are used to reflect sound into more beneficial areas of the hall and back to the stage.

Angles
The surfaces immediately to the side of the stage are angled away and down into the seating area. These angles are used to prevent sound from bouncing back and forth across the room, which would create distortion.

Wood
The hall's walls and floor are made of laminated Australian brush box. This material is used as it does not just reflect sound, but resonates slightly, granting it a much softer quality.

Wool
All the seats are lined with wool. This is used as the material is especially good at absorbing sound and, as the seats are the point of destination, stop it from rebounding and distorting.

"As it sends information to Apple, Siri has learnt from everything you've said in the last year"

Inside the iPhone 5

We take a look under the hood of the latest smartphone from Apple

The new iPhone is slimmer, lighter and more powerful than any of its predecessors

Just a year after the 4S was released, the iPhone 5 brings a selection of tech upgrades, including a taller 10.2-centimetre (four-inch) display and the new A6 processor. This brand-new chip makes the iPhone 5 up to twice as fast as the 4S. Plus, with double the RAM (random access memory) on board than before, the new smartphone is able to open apps quicker, run games more smoothly and offer faster web browsing.

It's thinner and lighter, but it also has 12 per cent less volume than the previous model; obviously this means that there is less space inside the body of the phone. However, Apple has managed to not only decrease the size, but also increase the battery life. This is thanks to the great strides in battery technology that have allowed the manufacturer to squeeze more power out of the cells.

These factors all work together so well because of the way Apple builds the iPhone. The A6 chip has been designed by Apple to make it ideal for this specific model, and even the dock connector and SIM tray are made to save as much space as possible in the frame. New display technology makes the screen thinner, while Siri has seen big improvements too. Because the 'personal assistant' sends information to Apple whenever it's used, Siri has learnt from everything you've said in the last year to offer the answers you want. This means the iPhone is smarter than ever.

iPhone 5 breakdown

Explore the core features of the brand-new iPhone which take it to another level

Unibody
The back and sides of the iPhone 5 are made from a single piece of aluminium, cut into a specific shape.

In-cell technology
This is the technology that has enabled Apple to make a display that is just 7.6mm (0.3in) thick, saving on space inside the iPhone 5.

Improvements in the iPhone 5

- 10.2cm (4in) Retina display
- Longer battery life
- 18 per cent thinner
- 4G LTE connectivity
- A6 chip for 2x faster computing
- 20 per cent lighter
- FaceTime HD camera

Flyover in Maps

When Apple built its new Maps application, it added a mode called Flyover. This allows you to pick a major city in the world, tap a button and see all the buildings in 3D. You can spin the view around, zoom in and out, and essentially 'fly' around the metropolis on your phone.

To do this, Apple flew helicopters and planes over many cities to build up 3D models of the buildings. The aircraft flew at various heights and angles, and took photos in every direction, allowing them to build up a database of images that show the area from every perspective. The images have been pieced together and formed into these virtual models. Then the photographs themselves have been applied to the models, so you can view a photorealistic re-creation of the city as you navigate around the screen.

2007 Steve Jobs takes to the stage at the Macworld conference and unveils the first iPhone (right).

2008 The App Store opens with 500 apps. Three days later there are 800, and 10 million downloads.

2010 Apple launches the iPhone 4, with a new kind of SIM card and a more customisable operating system (right).

2011 The iPhone 4S is released with iOS 5. However the model is initially marred by a number of faults.

2012 Apple releases the iPhone 5. In three days 5 million handsets were in the hands of customers.

DID YOU KNOW? *Steve Jobs was fired from Apple in 1985, but returned to the company in 1998 to make it a huge success*

Sapphire crystal lens
The camera on the back of the iPhone now features a sapphire crystal that's incredibly tough for scratch resistance.

iSight camera
This eight-megapixel camera is squeezed inside the thinner casing, but still provides high-quality photos and videos.

Heatsinks
Metallic shields called heatsinks cover the chips attached to the motherboard to help keep the phone cooler and ultimately more efficient.

Nano-SIM
Under this flap is where the iPhone's nano-SIM is stored. The new SIM is minuscule, creating even more space.

Lightning connector
At the bottom of the device is the new Lightning connector. It's tiny, saving even more space inside the phone.

Battery
The new battery in the iPhone is 3.8V, providing 5.45Wh of power.

Apple's A6 chip

The new A6 chip in the iPhone has been designed specifically by Apple to fit into the new handset. It's been built to provide a faster experience when using the phone from day to day, but also to provide more powerful graphics when playing games, for example.

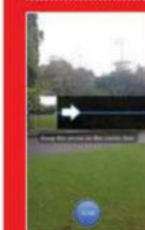
The A6 requires a lot of power, but because Apple designed the chip alongside the iPhone 5 and its operating system – iOS 6 – it could be optimised for this purpose.

The chip is based on the ARMv7 instruction set, but Apple has customised the chip to its own specifications. It has two cores, allowing the iPhone to split actions in half and perform them much quicker. It runs at 1.3GHz, which is fast for a smartphone, and the result is a noticeable speed boost compared with previous iPhones.

Understand Panorama

1 Prepare the camera
Tapping the Panorama mode will make the iPhone pause for a moment, as it needs to ready itself to capture multiple photos.

2 Portrait only
Panorama is restricted to portrait orientation to stop you from ending up with incredibly narrow photos.



3 Sweep
The iPhone's internal accelerometer and gyroscope track where the phone is moving and the iSight camera captures as you sweep.

4 Analysis
The iPhone analyses the photographs as you sweep to pick out any commonalities between shots. This is where they are joined.

5 Stitching
The iPhone will stitch the images together using an image analysis algorithm to create a single photo.

6 HD quality
The photos are saved at full resolution, offering super-crisp snaps that are up to 28 megapixels in size.

© iFixit.com

Once, central locking was groundbreaking, but things have moved on. A lot. Today's top cars are so clever they can help avert accidents, drastically reduce fuel use and keep us connected while on the road. We also explore Sir Richard Branson's sub, the Necker Nymph, and celebrate Russia's most successful fighter jet ever.

LEARN MORE

Supersmart car tech

2013 will see a wave of advanced autos hit the road, each boasting state-of-the-art features

From smart mechanical components through to complex computing systems, cars are increasingly being installed with technology that once would have been inconceivable. This technology enables them to accelerate quicker, stop faster, travel more quietly, reduce pollution and connect drivers with the world like never before.

Looking to 2013, this trend appears to be taking the automobile to a whole new level, supplementing the typical A-to-B with features that allow us to stream the latest audio-visual content while cruising down a motorway, for passengers to browse the web or control the vehicle's infotainment system remotely on long-haul journeys, make vehicle cabins whisper-quiet spaces where the relentless roar of the tarmac becomes a distant memory, and even enable drivers to relinquish control of braking and acceleration to an automated system almost entirely.

Indeed, as you shall see, the traditional concept of the car is changing rapidly, raising the benchmark of performance, comfort and accessibility through a variety of new technology. Here we select a handful of the most impressive tech, detailing how it works and why it's set to radically change how we travel.

Next-gen engineering of the 2013 Cadillac ATS

Take a closer look at the range of advanced features and technology packed into this superior sedan

DID YOU KNOW? *Ford's Auto Start-Stop system reduces in-city fuel consumption by ten per cent*

Connected devices can remotely control aspects of CUE, allowing passengers in the rear to change the music, for example

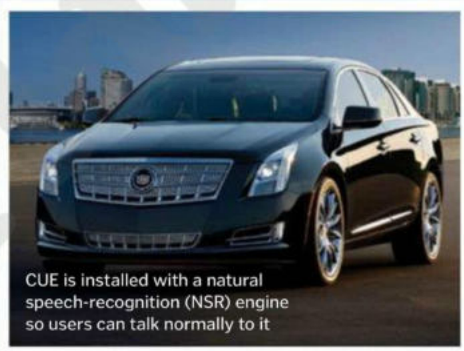
The new man/machine interface

While the hardware of the 2013 Cadillac ATS is impressive, arguably the smartest thing about the car is the CUE infotainment system

CUE – which stands for Cadillac User Experience – is a new infotainment system from the American automobile manufacturer that converges entertainment, navigation and communication tools – be they hardware or software – through a central in-car system. CUE operates off a modified Linux OS and is powered by an ARM 11 three-core CPU.

CUE's interface is a 20.3-centimetre (eight-inch), capacitive LCD touchscreen, which is embedded within the dashboard. Through this users have access to the car's features as well as those of many of their everyday electronic devices. This latter ability is achieved via Bluetooth, with up to ten Bluetooth-enabled gadgets capable of being hooked up to CUE at any one time. This option to synchronise devices allows the driver to access data – be it audio, video, imagery, emails, texts or contacts – without using the device itself, instead gaining access through the touchscreen or hands-free voice command.

The CUE hub is supported with proximity sensors that modulate the brightness of the LCD screen (when not in use it dims and when a hand approaches it lights up), haptic feedback, multitouch gesture support and a customisable home screen. There's the option to display speed and fuel stats alongside other useful applications such as maps.



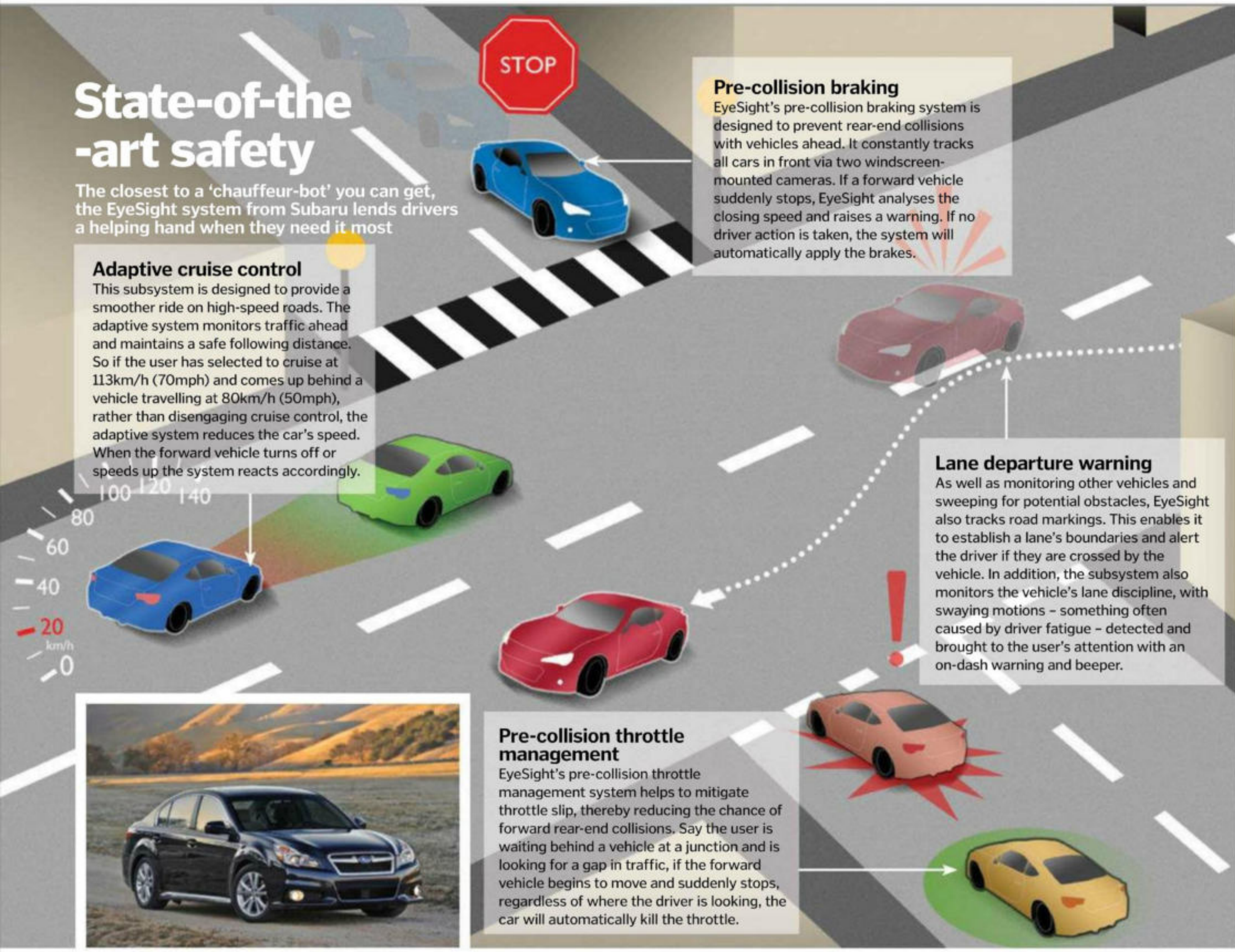
CUE is installed with a natural speech-recognition (NSR) engine so users can talk normally to it

© General Motors/Cadillac

"The Hotspot is easily taken out of the car, giving users super-fast internet anywhere"

State-of-the-art safety

The closest to a 'chauffeur-bot' you can get, the EyeSight system from Subaru lends drivers a helping hand when they need it most



Adaptive cruise control

This subsystem is designed to provide a smoother ride on high-speed roads. The adaptive system monitors traffic ahead and maintains a safe following distance. So if the user has selected to cruise at 113km/h (70mph) and comes up behind a vehicle travelling at 80km/h (50mph), rather than disengaging cruise control, the adaptive system reduces the car's speed. When the forward vehicle turns off or speeds up the system reacts accordingly.

Pre-collision braking

EyeSight's pre-collision braking system is designed to prevent rear-end collisions with vehicles ahead. It constantly tracks all cars in front via two windscreen-mounted cameras. If a forward vehicle suddenly stops, EyeSight analyses the closing speed and raises a warning. If no driver action is taken, the system will automatically apply the brakes.

Lane departure warning

As well as monitoring other vehicles and sweeping for potential obstacles, EyeSight also tracks road markings. This enables it to establish a lane's boundaries and alert the driver if they are crossed by the vehicle. In addition, the subsystem also monitors the vehicle's lane discipline, with swaying motions – something often caused by driver fatigue – detected and brought to the user's attention with an on-dash warning and beeper.

Pre-collision throttle management

EyeSight's pre-collision throttle management system helps to mitigate throttle slip, thereby reducing the chance of forward rear-end collisions. Say the user is waiting behind a vehicle at a junction and is looking for a gap in traffic, if the forward vehicle begins to move and suddenly stops, regardless of where the driver is looking, the car will automatically kill the throttle.

Wi-Fi hotspots

Adding Wi-Fi to a car is one thing, but adding in-car LTE Wi-Fi like BMW is something else altogether...

BMWs are going to be some of the most connected spaces on the road in 2013, with the manufacturer launching its LTE Car Hotspot in November 2012. The Hotspot – which is not new in itself – is essentially a mobile web connection point, with the system generating a cloud of connectivity via Wi-Fi, akin to a home router. What **is** new, however, is that the Hotspot is installed with long-term evolution (LTE) tech, which means it can throw out an exceptionally broad bandwidth, very low latency connection. Statistically this means users can connect to a network capable of data transfer rates of up to 150 megabytes per second, rather than the current standard 14-megabyte connections delivered by 3G hotspots. If that wasn't enough, the Hotspot is easily taken out the car, giving users super-fast internet anywhere.

Any WLAN-enabled device, such as most smartphones, can connect to the Hotspot while travelling

The Hotspot is powered by the car's internal battery

The Hotspot can even be removed from the car and used in remote locations

How many wipers can one factory make in a day?

A 3.5 million B 35 C 350,000

Answer:
More windscreen wiper blades are produced in Belgium each week than anywhere else in the world, with a single Bosch factory in Tienen producing approximately 350,000 per day in up to 700 different configurations.

DID YOU KNOW? BMW is the first manufacturer to develop an in-car LTE Wi-Fi hotspot

Auto start-stop

A system that is so advanced it can automatically suspend and then reactivate a car's engine in a fraction of a second

Ford is delivering a clever new system in its 2013 Fusion model that goes a long way to reducing the estimated 7.2 billion litres (1.9 billion gallons) of fuel wasted in congestion in 2011.

The Auto Start-Stop system is a technological suite that immediately suspends engine operation when a vehicle is stationary, thereby reducing the amount of hydrocarbons burned while in heavy traffic. Crucially, the system also fully switches the engine back on automatically – and in a fraction of a second – meaning the driver can accelerate away smoothly.

The Start-Stop system works through the brake. When the car is stationary and the user applies the foot brake, engine activity is suspended. When the driver releases the brake, engine activity is resumed. Start-Stop has been programmed to compensate for engine-reliant operations such as maintaining optimal temperature ranges, as well as factors like external temperature.

Active noise cancellation

Capable of reducing low-frequency sounds from both the engine bay and outside the cabin, Ford's ANC is offering drivers and passengers alike great peace of mind

When travelling at speed, no matter how well insulated a vehicle, noise can affect ride comfort. Even if an engine is capable of granting faster acceleration, often it must be limited to maintain acceptable noise levels.

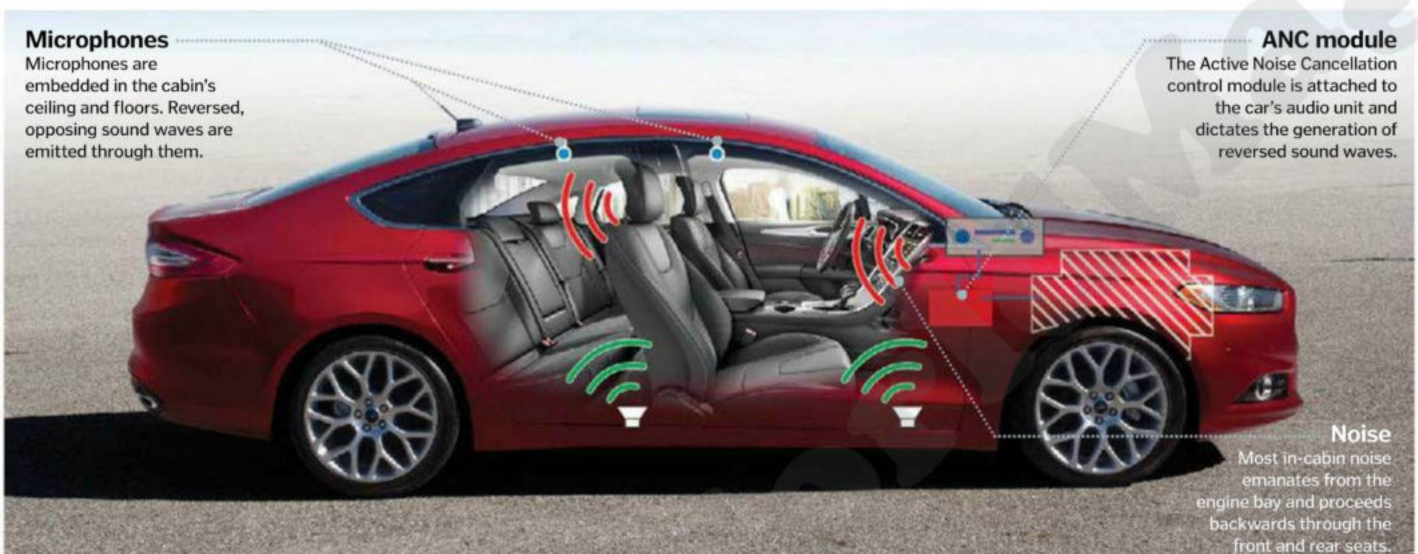
This compromise is being tackled in 2013 by Ford's Active Noise Cancellation (ANC) system, an in-car module that continuously cancels out objectionable sounds from the engine bay and road surface. It does this using a series of microphones throughout the cabin and a control system attached to the car's audio system. Through these ANC generates sound waves that oppose those entering the cabin, before directing them through the microphones. These reversed waves proceed to destabilise and cancel out those from the engine and road, creating a significantly quieter cabin. Pretty smart, right? Well, actually it gets smarter. As a large percentage of the engine noise is negated in the cabin, that has allowed Ford to tune its cars' engines to deliver better performance and fuel economy, all the while maintaining a peaceful interior.

Best of the rest car tech

1 Key-Free System
Ford's Key-Free System replaces the standard car key with a passive key that automatically unlocks the car when in close vicinity.

2 Magic Vision
Mercedes-Benz's Magic Vision technology installs spray washers into each of the vehicle's windscreen wipers, aiding their ability to keep the glass spotless.

3 Cylinder Management System
Audi's new Cylinder Management System shuts down certain engine cylinders when they're not in use, improving fuel economy.



"From advanced materials to the unique positive buoyancy system, the Nymph is one of a kind"

How personal subs work

Dive in and learn how the most advanced personal submersible in the world navigates the ocean

The Necker Nymph is a personal submersible designed by Hawkes Ocean Technologies that allows up to three people to essentially 'fly' underwater. The sub, which is the first of the company's DeepFlight Merlin-class crafts – the fifth generation of winged submersibles it has built – is owned by Sir Richard Branson's Virgin Oceanic programme and operates off Necker Island in the British Virgin Islands.

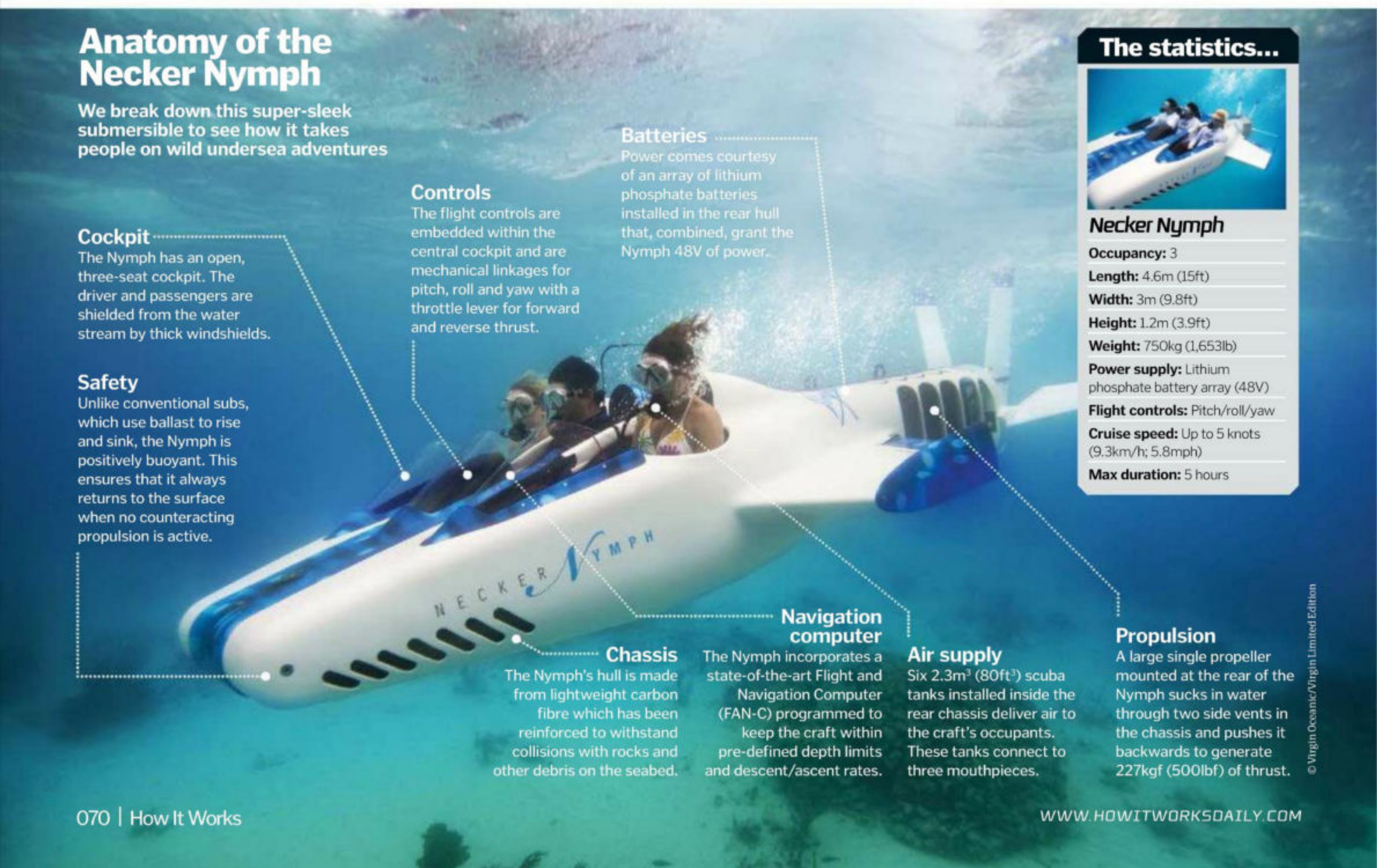
The Nymph is arguably the most advanced personal submersible in the world for a good reason. It combines the most state-of-the-art technologies available right now into an open cockpit marine craft capable of literally soaring through the ocean (see 'Anatomy of the Necker Nymph' below for more details).

From advanced construction materials, such as the reinforced carbon fibre used in the chassis, through to the unique positive buoyancy system that allows the craft to always return to the surface – even in the event of a power failure – the Nymph is one of a kind. The submersible also boasts some clever computing tech in the shape of the Flight and Navigation Computer (FAN-C) with a heads-up graphic display that automatically maintains optimal depth range and diving speeds.

Thanks to these features, as well as its cutting-edge mechanical linkage controls and powerful 48-volt lithium phosphate power supply, the Nymph is even capable of extreme hydrobatic manoeuvres, easily performing 360-degree rolls and loops, for instance.

The Nymph's home

The Necker Nymph, the first of Hawkes Ocean Technologies' DeepFlight Merlin subs, is located on Necker Island, home to British billionaire Sir Richard Branson, as well as the Necker Island Resort, run by Virgin Limited Edition. The Nymph is used by Branson himself and any of the 28 guests who can stay on the island at any one time. Aside from the Nymph, the island also features two private beaches, a series of large private swimming pools and an array of water sports equipment. Sadly, at $42,500 per night for use of the entire island, taking the Nymph for a spin is out of most people's budgets.



The statistics...

Necker Nymph

Occupancy: 3
Length: 4.6m (15ft)
Width: 3m (9.8ft)
Height: 1.2m (3.9ft)
Weight: 750kg (1,653lb)
Power supply: Lithium phosphate battery array (48V)
Flight controls: Pitch/roll/yaw
Cruise speed: Up to 5 knots (9.3km/h; 5.8mph)
Max duration: 5 hours

"It has seen significant combat in its 19-year service, including deployment in the Persian Gulf War"

Mikoyan MiG-29

Russia's primary fighter jet combines a host of advanced tech to create an agile and deadly aircraft

Often overlooked in the west due to its Soviet Union origins in the Eighties, the Mikoyan MiG-29 is actually one of the world's most prolific fighter jets, with over 1,600 units in operation around the globe. For a little perspective, there are only just over 300 Eurofighter Typhoons currently in operation across the planet, a number that is unlikely to ever exceed the 500 mark.

So why is this Russian plane so successful? For starters, it's great value for money – just shy of £18 million ($29 million), compared to the £64.8 million ($104.6 million) Typhoon.

The MiG-29 is a fourth-generation fighter jet designed for an air supremacy role, which involves infiltrating and seizing enemy airspace through force. It comes in a wide range of variants, with both legacy and current production models (such as the MiG-29K and MiG-29M) in operation, and has seen significant combat throughout its 19-year service, including deployment in the Persian Gulf War.

The aircraft is built around an aluminium airframe, which is bolstered with advanced composite materials. This airframe is designed for up to 9g manoeuvres, making the jet insanely agile and quite easy to fly for skilled pilots – hence why it's often used at air shows.

Surrounding the airframe lies an elegantly sculpted titanium/aluminium alloy fuselage that tapers in from a wide rear to a raised, 'swan neck' cockpit and elongated nose cone. From the fuselage extends the aeroplane's mid-mounted swept wings, each of which is installed with leading-edge root extensions.

The MiG-29 is powered by two widely spaced Klimov RD-33 afterburning turbofans that, besides granting a top speed of 2,400 kilometres (1,490 miles) per hour, also help reduce effective wing loading. This is thanks to their wide spacing, with the area between them generating extra lift. The engines are fed by an internal fuel system that parses its total reserves down into a series of sub-tanks.

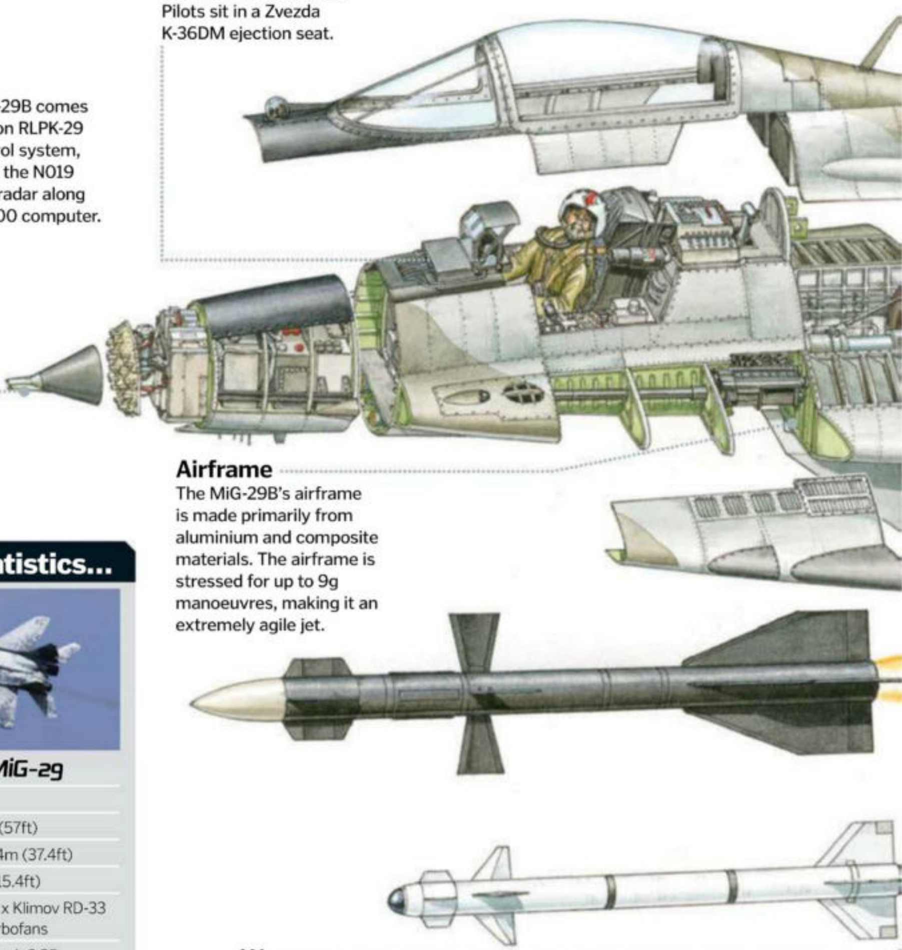
The MiG-29 comes packing a vast arsenal too. Each jet is fitted with seven hardpoints capable of carrying a wide array of missiles and bombs, or external fuel tanks for longer missions.

Anatomy of a MiG-29B

The essential hardware of this Russian air superiority fighter revealed

Cockpit
The MiG-29B's cockpit has a bubble canopy and comes equipped with a conventional centre stick, left-hand throttle controls and a heads-up display. Pilots sit in a Zvezda K-36DM ejection seat.

Sensors
The stock MiG-29B comes with a Phazotron RLPK-29 radar fire control system, which includes the N019 pulse-Doppler radar along with an NII Ts100 computer.



Airframe
The MiG-29B's airframe is made primarily from aluminium and composite materials. The airframe is stressed for up to 9g manoeuvres, making it an extremely agile jet.

Weapons
The MiG-29B comes with seven hardpoints, each capable of carrying a selection of arms (such as R-73 air-to-air missiles) and bombs. In addition, it carries a single GSh-30-1 30mm (1.2in) cannon.

The statistics...

Mikoyan MiG-29

Crew: 1

Length: 17.4m (57ft)

Wingspan: 11.4m (37.4ft)

Height: 4.7m (15.4ft)

Powerplant: 2 x Klimov RD-33 afterburning turbofans

Max speed: Mach 2.25 (2,400km/h; 1,490mph)

Max range: 1,430km (888mi)

Max altitude: 18,013m (59,100ft)

Hardpoints: 7

Max payload: 3,500kg (7,720lb)

5 TOP FACTS
MIG-29 TRIVIA

Origin
1 The MiG-29 was born out of the Soviet Advanced Lightweight Tactical Fighter programme in the Seventies. This programme overshadowed the USA's Fighting Falcon programme.

Loss
2 The MiG-29 entered service successfully in 1983 at the Kubinka Air Base near Moscow. But this only came after two prototypes were lost in engine-related accidents.

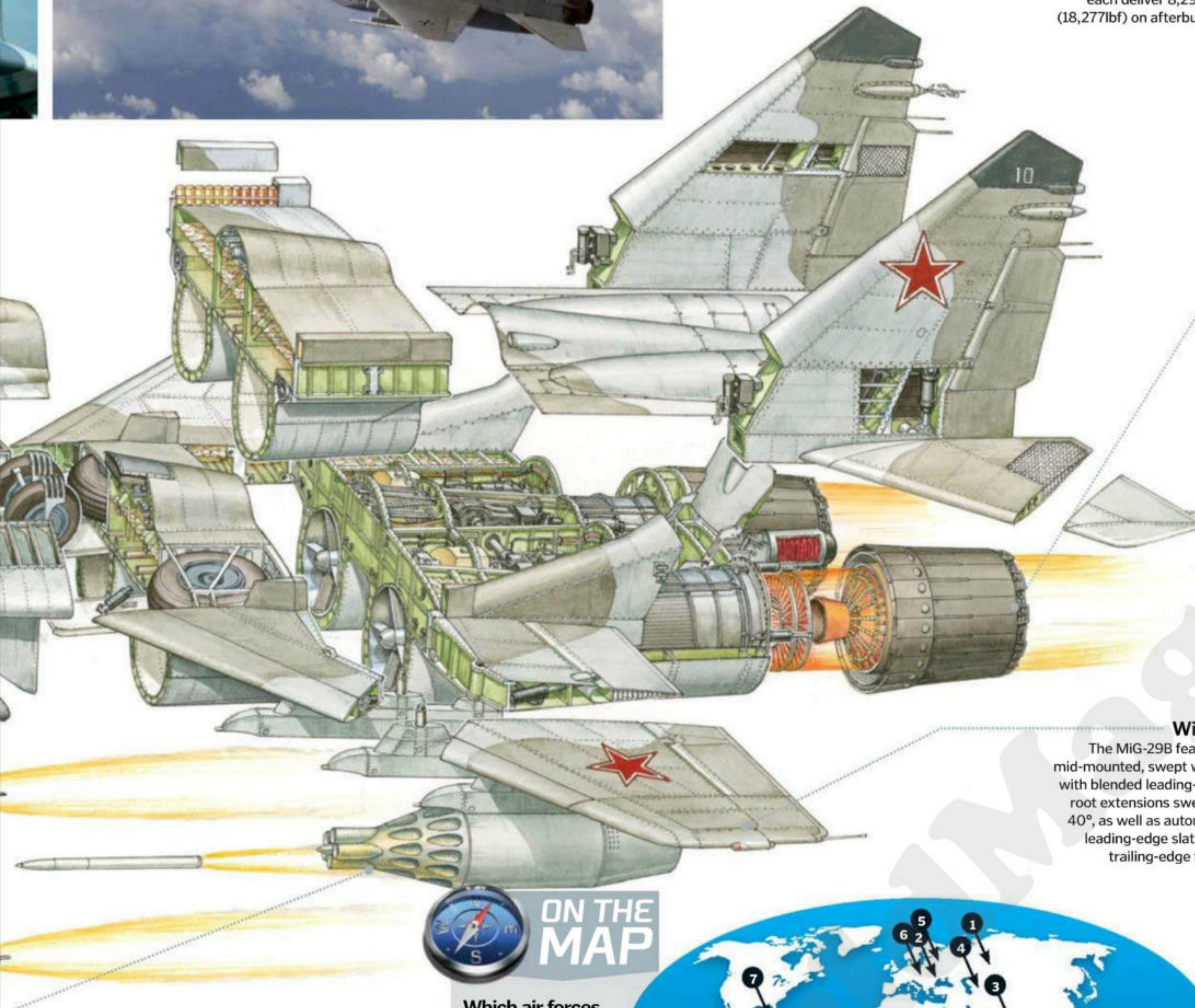
Fulcrum
3 The MiG-29 was designated the NATO reporting name 'Fulcrum-A' post-introduction, a name that would eventually be adopted by its Russian pilots as a nickname.

Fill 'er up
4 The MiG-29B has a fuel capacity of 4,365 litres natively, with extra external fuel tanks fixable to the wings. The internal fuel reserve is divided into six sub-tanks.

Tattoo
5 In 1993 two MiG-29s of the Russian Air Force collided in mid-air during a routine at the Royal International Air Tattoo. Luckily no harm came to either the pilots or spectators.

DID YOU KNOW? Today a Mikoyan MiG-29 will set you back around £17.9 million ($29 million)

Powerplant
The fighter jet comes installed with two Klimov RD-33 afterburning turbofans, which are widely spaced to reduce wing loading and improve manoeuvrability. They each deliver 8,290kgf (18,277lbf) on afterburner.



Wings
The MiG-29B features mid-mounted, swept wings with blended leading-edge root extensions swept at 40°, as well as automatic leading-edge slats and trailing-edge flaps.

ON THE MAP

Which air forces fly MiG-29s?

1 Russia: 291
2 Ukraine: 80
3 India: 67
4 Uzbekistan: 60
5 Belarus: 41
6 Poland: 36
7 Cuba: 4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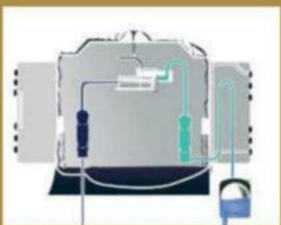
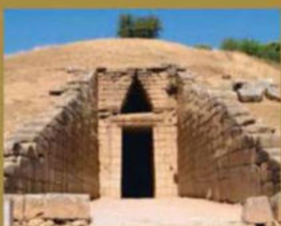
categories explained: Ancient world | Buildings & places | Industry | Inventions | Medieval times | People & places | Weapons & war | General

This month get to know one of the most famous dinosaurs ever – the plated herbivore Stegosaurus. Find out how it protected itself, what it ate and how it got around. Elsewhere, learn about the beehive-shaped tombs of the Mycenaean elite, one of the first commercial fridges and explore China's grand Zijin Cheng (Forbidden City).



78 Monitor-top fridges



79 Greek tombs

80 Forbidden City

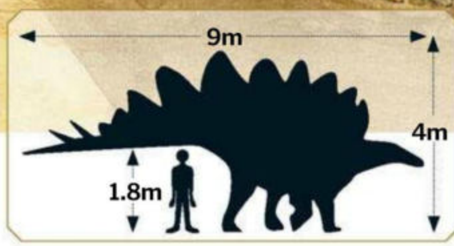
LEARN MORE

The bony plates along the Stegosaurus's back were probably used for display rather than as a form of defence

The statistics...

Stegosaurus

Family: Stegosauridae
Genus: Stegosaurus
Period: Late Jurassic (156-144 MYA)
Length: 8-9m (26.2-29.5ft)
Height: 2.8-4m (9.2-13.1ft)
Weight: 3,100kg (6,800lb)



Stegosaurus

One of the most well known of the dinosaurs, the Stegosaurus boasted a series of diamond-shaped bone plates and a tail that could kill

5 TOP FACTS STEGOSAURUS

Plate debate
1 The arrangement of the Stegosaurus's plates has been a major controversy in the palaeontology sphere. Academics have suggested four possible configurations.

Hip to be brainy
2 On finding a large canal in the hip region of the spine, some have argued it could have been the place of a secondary 'brain' structure, responsible for controlling rear reflexes.

Prosperous dino
3 Evidence implies Stegosaurus was a very successful species, with fossilised remains widely distributed geographically and temporally across the entire Late Jurassic period.

Four footed
4 When the first Stegosaurus remains were unearthed in 1877, it was believed to be a bipedal creature. But as new specimens emerged, it was reclassified as a quadruped.

Species
5 There are four confirmed species: S armatus, S stenops, S sulcatus and S longispinus. There are also four unconfirmed species from incomplete specimens.

DID YOU KNOW? *Some palaeontologists have suggested Stegosaurus's plates were used for regulating body temperature*

Maybe the most iconic genus of dinosaurs ever excavated, the Stegosaurus was a herbivorous titan, capable of consuming huge quantities of low-level foliage while protecting itself from predators with its vast armoured frame and potentially lethal spiked tail.

The first example of Stegosaurus – from which its family name, Stegosauridae, derived – was unearthed in 1877 and since then four confirmed species of the dinosaur have been officially identified. Each species demonstrates a similar structure and feature set, with each animal epitomising a large quadruped, sporting a series of diamond-shaped plates along its back. These large creatures were over eight metres (26 feet) long and were heavily built at over 3,000 kilograms (6,614 pounds).

Interestingly, it's these plates that palaeontologists and academics know the least about, with a variety of arrangements, structures and uses suggested. When first unearthed it was speculated that they were used as a form of armoured defence against carnivorous predators. However, their positioning along the back and apparent bluntness has led to this theory being largely dismissed today. Instead, academics suggest that the plates were used as a decorative feature – perhaps in mating displays or to ward off Stegosaurus rivals in territory disputes.

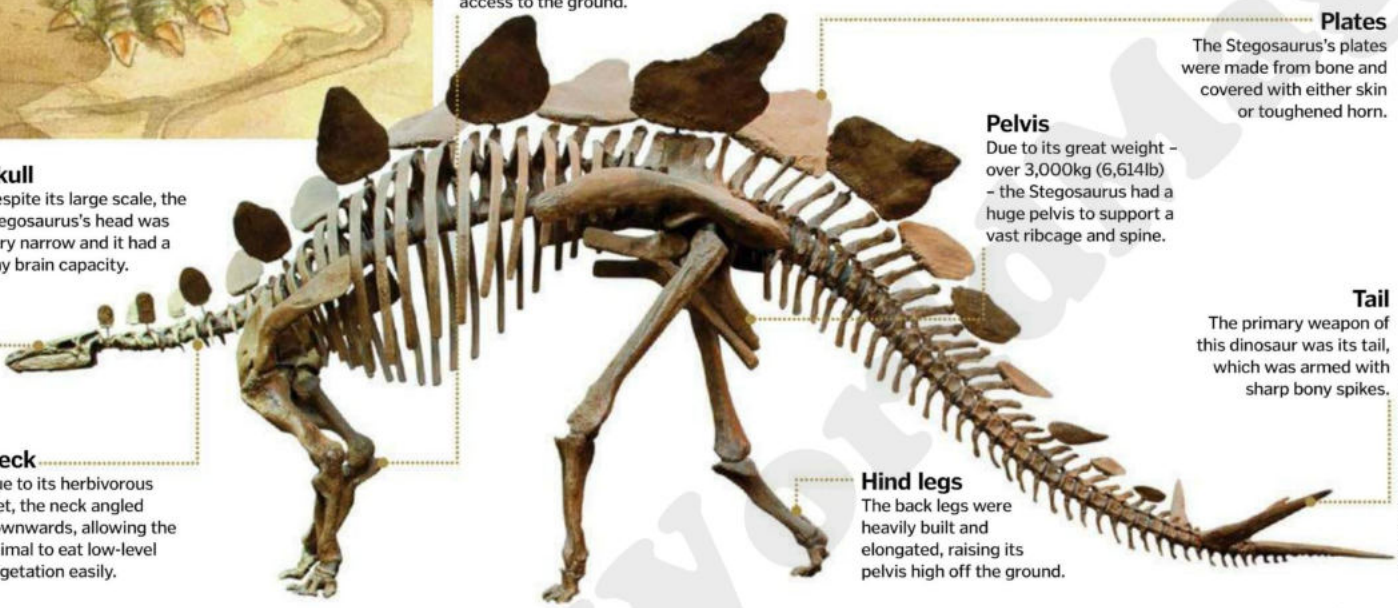
The field of palaeobiology reveals almost everything else about this genus. Studying fossilised evidence it is clear that due to Stegosaurus's very small and narrow skull, they had a tiny brain and so were not very intelligent – something seemingly confirmed by their primitive and mundane feeding habits. The low level of the animal's neck, short but bulky forelegs and raised pelvis/elongated hind legs indicate that Stegosaurus spent much of its daily routine consuming large quantities of low-lying foliage (such as ferns, cycads and conifers). This is confirmed by the shape andformation of its teeth and a low bite force.

Upon closer inspection of the dinosaur's legs it is also clear that it could not move very quickly. This is apparent as the discrepancy in size between the front and hind legs is so great that, if the creature ran at over eight kilometres (five miles) per hour, its longer back legs would cross over the forelegs leading it to fall.

Despite these shortcomings, Stegosaurus wasn't totally defenceless, as it boasted a flexible, armour-plated and spiked tail. Taking Stegosaurus stenops as an example, the dinosaur had four dermal tail spikes of approximately 75 centimetres (29.5 inches) in length each, which extended out from the tail slightly off the horizontal plane. These spikes enabled the Stegosaurus to whip its tail and puncture the flesh of any attackers.

Stegosaurus anatomy

Understand the biological structure of this distinctive dino from the inside out



© Eva Kröcher; Alamy; Nobu Tamura

"These refrigeration units worked under the same principles as modern fridges"

How did the first electric refrigerators work?

Often taken for granted today, once refrigerators were a groundbreaking and luxury appliance

Back in the Twenties, one electric refrigeration company dominated the market: Kelvinator. Its wooden cold box/compressor combo cost $714 (nearly $9,800/£6,100 today) – way beyond the pocket of the average household. So, with the goal of bringing more affordable refrigerators to the masses, General Electric ploughed $18 million into making the GE 'Monitor-top' fridge.

They were called Monitor-tops because the cabinet was all steel and the condenser was sealed in a cylindrical enclosure on top, which made it look like the turret from a 19th-century ironclad warship – the USS Monitor.

These refrigeration units worked under the same principles as modern fridges. By using a compressor, a circulating refrigerant was transformed from vapour into a liquid and cooled to near-room temperature under pressure, before being released back into circulation. The sudden change in pressure caused the refrigerant to turn into a vapour again, which had to draw heat from the air inside the cabinet, ultimately cooling it.

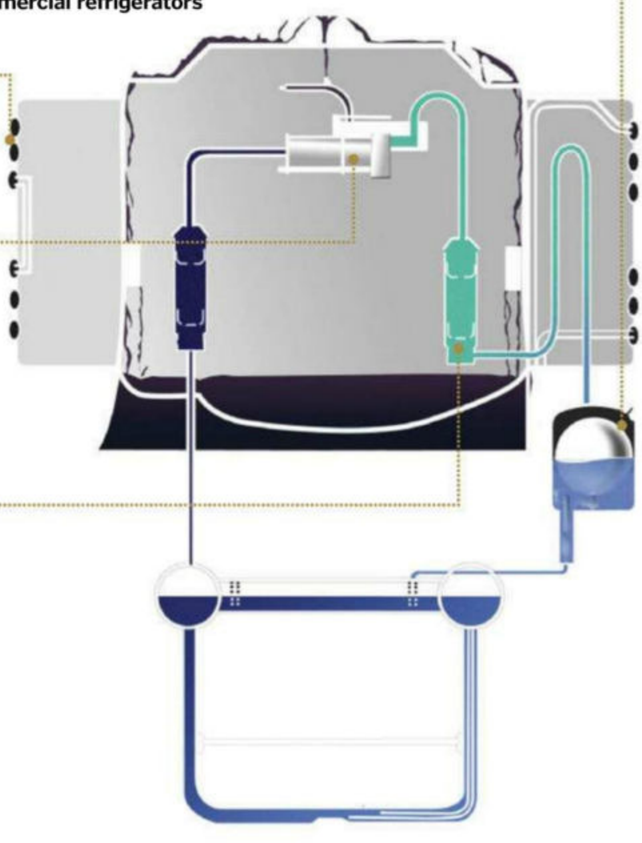
Several models of the Monitor-top were made, including two and three-door units, but the most popular was the single-door variant, which originally sold for $300 in 1927.

Toxic origins

Today, the inert tetrafluoroethane gas R134a is commonly used in fridges and freezers, but in the Twenties refrigerants like sulphur dioxide, methyl formate and methyl chloride were used. These are quite toxic: sulphur dioxide causes burns on contact and can damage vision, methyl formate is highly flammable, while methyl chloride, or chloromethane, can cause dizziness, nausea and even seizures at high concentrations. These nastier chemical refrigerants were replaced by Freon, a relatively harmless gas that, nevertheless, was banned in the production of new fridges in 1990 over concerns about CFCs' effect on the ozone layer. Monitor-top fridges have become quite collectable now, the steel build ensuring many have survived for nearly a century. They are usually converted, with the dangerous gases removed and a modern compressor system installed to be eco-friendly.

Inside a Monitor-top fridge

HIW highlights the major components that made up one of the first commercial refrigerators



Refrigerant vapour
The cool refrigerant liquid is passed through a valve and expands back to a partial gas state, taking heat from the air in the cabinet in the process.

Heat-exchanging pipes
The liquid refrigerant, warm from compression, is passed around a series of pipes and cooled to room temperature.

Compressor pump
This pushes the refrigerant around the unit and compresses the refrigeration vapour.

Liquid refrigerant
The compressor applies pressure to the methyl formate gas in the Monitor-top fridge, which transforms it into a liquid.

© Getty

KEY DATES
MYCENAEAN ERA

- **1900 BCE** The cultural period of Mycenaean Greece begins during the Bronze Age, taking its name from the city of Mycenae.
- **1600** Mycenaean Greece flourishes and reaches an apex under the influences of their warrior-centred culture.
- **1400** Mycenaeans reach the peak of their territorial expansion via conquest by taking Minoan Crete.
- **1194** According to Eratosthenes, Mycenaeans led by King Agamemnon begin their assault on Troy (right).

- **1100** The Mycenaean period ends (right), largely superseded by the Dorian peoples.

DID YOU KNOW? *Tholos (beehive) tombs emerged in Mycenaean Greece in the Late Bronze Age*

Greek tomb construction

Learn about the unique structures in which the elite of these Ancient Greek people were buried

There were two main types of Mycenaean tomb: chamber tombs and tholos tombs. The former predates the latter and consisted of a rhomboidal chamber cut into rock/earth and finished with a square stone pyramid on the top. No examples of these tombs have been found in modern times, however they are detailed in ledgers of the ancient Babylonian city of Uruk.

The latter, which became the more common tomb after 1500 BCE, is of a grander design. Tholos tombs, which resemble the shape of a beehive, were conical, false-domed chambers built out of mud bricks and stone. The bricks were laid in a circle on top of one another up to a tapered centre point. The entire dome was then covered by an earthen mound (tumulus).

These beehive tombs were accessed via a long approach corridor, or passage, that was known as a dromos, which culminated in a large entranceway, called a stomion. The stomion consisted of a large rectangular brick opening commonly flanked by two stone columns and topped with a single giant stone mantle. Above the mantle a triangular hole was often filled with a decorative relief sculpture.

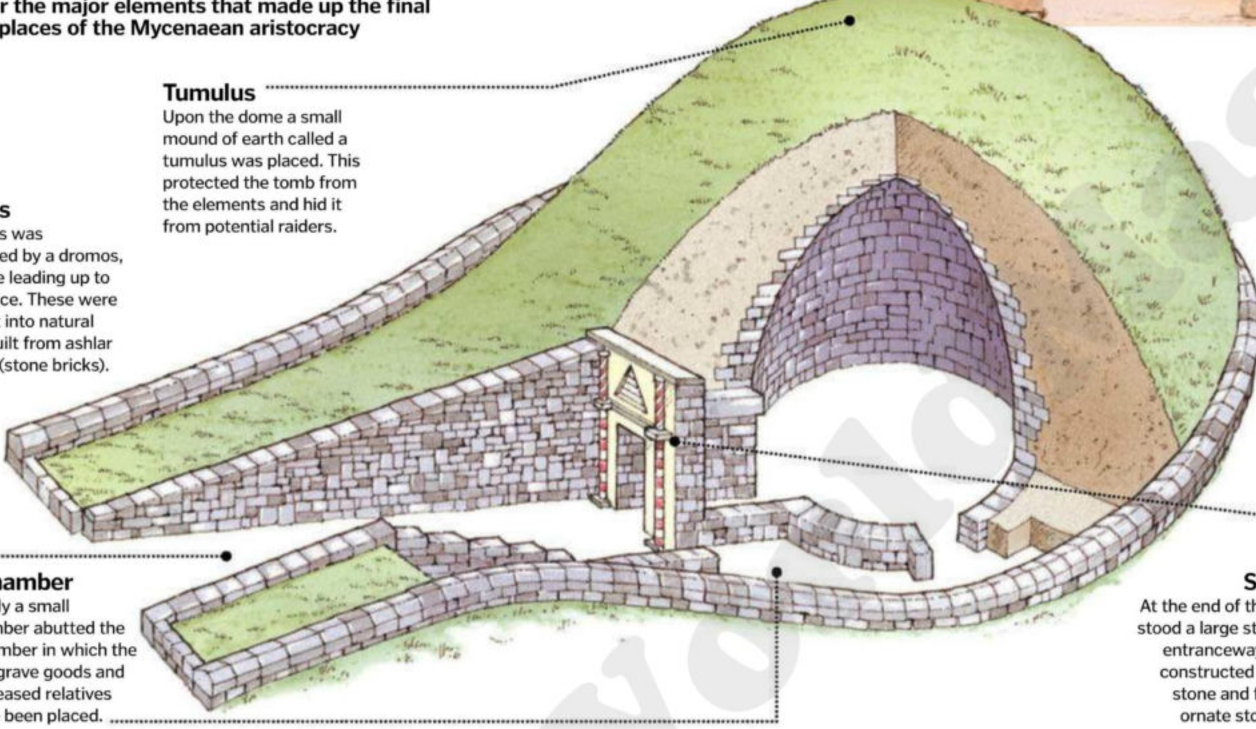
Inside, off the main conical chamber, lay an antechamber, which was typically rectangular. This could be used either for burials – other family members – or more likely grave goods, such as jewellery and weapons. There's evidence that both the antechamber and main stomion were installed with wooden doors, the latter set slightly back from the main façade.

Who were the Mycenaeans?

The Mycenaean civilisation occupied much of modern-day central Greece and flourished between 1600 and 1100 BCE. Unlike the earlier Minoan settlers of the area whose society expanded and prospered through trade, the Mycenaeans advanced theirs through military conquest. One of the most notable examples of the Mycenaean expansion through war is recorded in Homer's *The Iliad*, where the king of Mycenae, Agamemnon, and the united forces of Greece took the city of Ilium (Troy) in north-west Anatolia (Turkey). Another advance saw the Mycenaeans capture the island of Crete.

A tholos tomb unearthed

Discover the major elements that made up the final resting places of the Mycenaean aristocracy



Tumulus
Upon the dome a small mound of earth called a tumulus was placed. This protected the tomb from the elements and hid it from potential raiders.

Dromos
The tholos was approached by a dromos, an avenue leading up to its entrance. These were either cut into natural rock or built from ashlar masonry (stone bricks).

Antechamber
Commonly a small antechamber abutted the main chamber in which the person's grave goods and even deceased relatives may have been placed.

Stomion
At the end of the dromos stood a large stomion, an entranceway typically constructed out of cut stone and flanked by ornate stone pillars.

"The city itself took over 14 years to complete [1406-1420] and the efforts of 1 million labourers"

Inside the Forbidden City

Home to Chinese emperors for over 500 years, the Forbidden City in Beijing was the epicentre of the nation's political and spiritual rule

The Forbidden City (Zijin Cheng) was the Chinese imperial palace from 1420 right up until 1924. From the Ming Dynasty to the end of the Qing Dynasty the vast complex – which measures in at 720,000 square metres (7.75 million square feet) and is located at the centre of the imperial city – served as the home of the emperor, his household and officials, as well as the political, military and ceremonial heart of the entire empire.

The Forbidden City complex contained 980 buildings of varying types and functions, ranging from libraries, through to offices of state, armouries and dwellings, on to council rooms and meditation centres. In addition, a multitude of courtyards, gardens, fountains and artificial streams linked each section and the entire city was surrounded by a 7.9-metre (26-foot)-high fortified earth and brick wall.

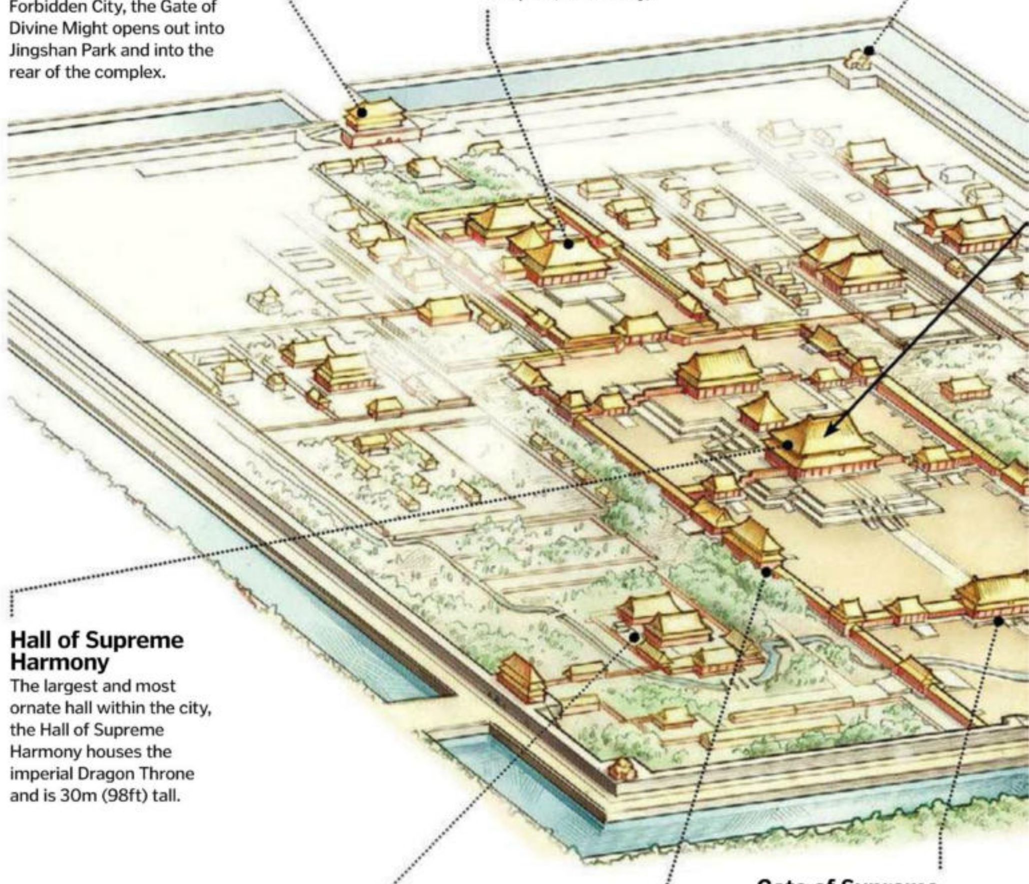
At the centre of the complex lay the 30-metre (98-foot)-high Hall of Supreme Harmony, the figurative heart of the Chinese empire and location of the Dragon Throne, the official seat of the emperor. From here, the Chinese premier ruled the country and, throughout its various rooms, would sign official documents, hold council with his advisors, meet foreign dignitaries and plan military conquests.

The city itself took over 14 years to complete (1406-1420) and the efforts of 1 million labourers. The design of the city, from its overall layout to individual buildings, was based on the prevalent philosophical and religious ideology of the time. Examples of this include the inner and outer courts featuring halls in groups of three, representing the shape of the Qian trigram (an interpretation of heaven); the residence of the prince having green tiles (a colour associated with growth); and the central north-south axis both extending to that of the wider city of Beijing and being in alignment with Xanadu, a former capital city.

Since 1925 the Palace Museum, a governmental body which oversees its preservation, has managed the site as well as its vast collections of ancient artefacts. Depsite its name, anyone can go to the Forbidden City today, and millions visit every year.

City guide

Take a tour of the key buildings and features in this impressive 15th-century complex



Gate of Divine Might
The northern gate of the Forbidden City, the Gate of Divine Might opens out into Jingshan Park and into the rear of the complex.

Palace of Heavenly Purity
During the Ming Dynasty this palace was home to the emperor. It had 27 beds across nine rooms that the emperor could sleep in (for security).

Guard towers
In each corner of the city are defensive guard towers that link the complex's 7.9m (26ft)-high walls.

Hall of Supreme Harmony
The largest and most ornate hall within the city, the Hall of Supreme Harmony houses the imperial Dragon Throne and is 30m (98ft) tall.

Gate of Supreme Harmony
Built during the Ming Dynasty, the Gate of Supreme Harmony is surrounded by incense burners and leads to Harmony Square.

Hall of Military Eminence
Despite its name, the Hall of Military Eminence was actually used to house, study and censor books by high-ranking officials. In addition, sometimes court would be held here.

Hall of Mental Cultivation
Home to emperors throughout the Ming and Qing Dynasties, this hall is one of the smallest to be found within the Forbidden City and contained a living suite and office.

5 TOP FACTS
FORBIDDEN CITY

Yellow
1 Almost all the rooftops in the Forbidden City are finished with yellow glazed tiles. This colour was chosen as, at the time, yellow was the official colour of the Chinese emperor.

Statuettes
2 Each building's roof is decorated with a line of small statues, with the importance of the building determining how many it featured. The highest number is ten.

Time
3 The Forbidden City is home to one of the world's largest collections of timepieces, with over a thousand examples dating from the 18th and 19th centuries within its walls.

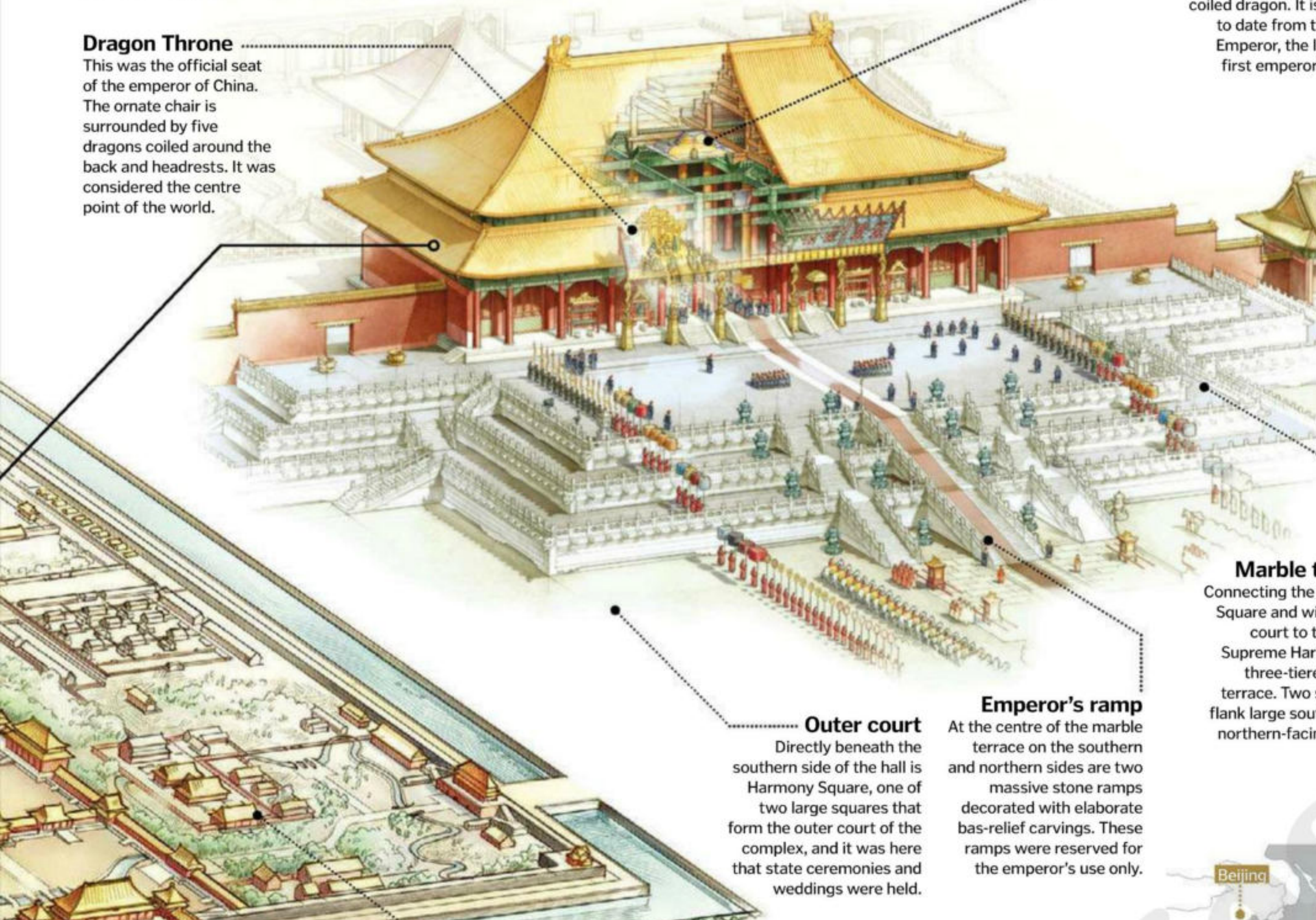
Complex
4 The Forbidden City is very large, containing over 980 buildings of varying sizes over a 720,000m² (7,750,000ft²) complex. Thousands of tourists visit every day.

Heritage
5 Since 1925 the city has been under the charge of the Palace Museum, which manages the site's many ancient artefacts. It was declared a UNESCO World Heritage Site in 1987.

DID YOU KNOW? The Forbidden City was so-named because no one could enter or leave without the emperor's permission

The Hall of Supreme Harmony

Explore the heart of the Forbidden City and the empire – the building that houses the imperial Dragon Throne



Dragon Throne
This was the official seat of the emperor of China. The ornate chair is surrounded by five dragons coiled around the back and headrests. It was considered the centre point of the world.

Ceiling
Set into the hall's ceiling is an intricate caisson decorated with a large, coiled dragon. It is believed to date from the Yellow Emperor, the legendary first emperor of China.

Marble terrace
Connecting the Harmony Square and wider outer court to the Hall of Supreme Harmony is a three-tiered marble terrace. Two stairways flank large southern and northern-facing ramps.

Emperor's ramp
At the centre of the marble terrace on the southern and northern sides are two massive stone ramps decorated with elaborate bas-relief carvings. These ramps were reserved for the emperor's use only.

Outer court
Directly beneath the southern side of the hall is Harmony Square, one of two large squares that form the outer court of the complex, and it was here that state ceremonies and weddings were held.

Hall of Literary Glory
Initially built as a dwelling and then converted into a meeting place for the emperor and his scholars, this hall was eventually turned into an imperial library and printing house.

Meridian Gate
The largest gate of the Forbidden City, the southern-facing, five-arched Meridian Gate leads into the complex from the wider grounds.

BRAIN DUMP

Because enquiring minds want to know...

Ask your questions

Send us your queries using one of the methods opposite and we'll get them answered

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in Zoology from Oxford University and another in Real-time Computing. He's been writing about science and tech since before the web. His science-fiction novel A Jar Of Wasps is published by Anarchy Books.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!

Alexandra Cheung

With degrees from the University of Nottingham and Imperial College, Alex has worked for several scientific organisations including London's Science Museum, CERN and the Institute of Physics. She lives in Ho Chi Minh City, Vietnam.

Dave Roos

A freelance writer based in the USA, Dave has researched and written about every conceivable topic, from the history of baseball to the expansion of the universe. Among his many qualities are an insatiable curiosity and a passion for research.

Michael Simpson

Michael has a doctorate in moss and teaching awards from the University of Alberta. While not working as an expat botanist and environmental consultant, he writes for magazines and websites on TV programmes, technology and science.

Are there any freshwater sharks?

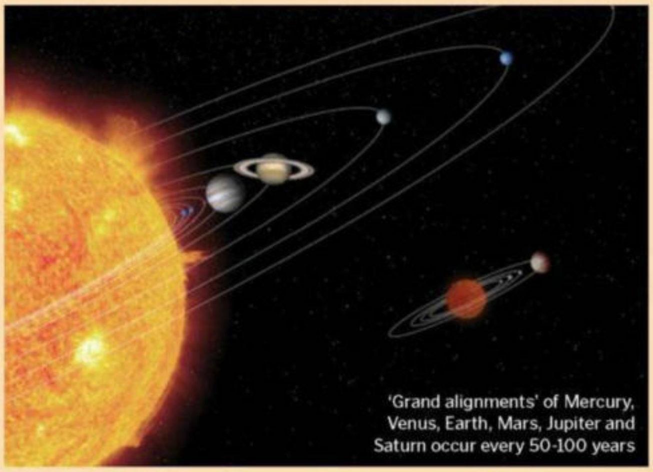
Adam Staines

Several species of shark are known to live in a freshwater environment, but whether they should be considered true freshwater fish is debatable.

Probably the most mysterious are the river sharks of the genus Glyphis. Fewer than ten species have been identified in watercourses around south-east Asia and Australia, with some still waiting to be officially classified, and all are extremely rare.

Much better known is the bull shark (Carcharhinus leucas). This worldwide species enters warm water estuaries from the ocean and then swims into fresher water upstream. If you see an adult bull shark from a kayak, you might wish you had a bigger boat: they are large and aggressive predators and have been known to attack humans. A notable characteristic of bull sharks living in freshwater habitats is that they excrete a large amount of urine. Sharks that evolved in the ocean have a great deal of salt naturally present in their bodies to prevent them from losing water to the sea through osmosis. In the non-saline water of rivers and lakes bull sharks have the opposite problem: they would swell up like a water balloon without a way to get rid of the excess freshwater that their bodies absorb. Hence, they pee a lot!

Michael Simpson



'Grand alignments' of Mercury, Venus, Earth, Mars, Jupiter and Saturn occur every 50-100 years

Will all the planets in our Solar System ever be lined up?

Tom Jackson

It depends on what you mean by 'lined up'. The planets can never actually fall in a straight line. Their orbits are just too different. But if you're talking about a loose, wobbly sort of line, it's happened before, to varying degrees. We've had major planetary alignments in 1962, 1980 and 2000. And earlier in 2012, several of the planets – Mercury, Mars, Venus and Jupiter – could be viewed in the night sky for a few weeks. Despite speculation that a planetary alignment at the end of this year could lead to cataclysmic events, Earth has been just fine during previous alignments, so there's no need to panic!
Shanna Freeman

What is toothpaste made of and is it considered a solid or a liquid?

Matt Pryse

Look at the back of your tube of toothpaste and you'll find a surprisingly long list of ingredients, carefully formulated to look after your pearly whites. First of all, you will find an abrasive such as silica, which shifts stubborn stains. Next, water acts as a solvent, combining the other ingredients together and giving the toothpaste the right consistency. A humectant (glycerin or sorbitol) plays a similar role, keeping the toothpaste well-mixed and preventing it from drying out should you leave the cap off. A surfactant such as sodium lauryl sulphate (SLS) creates foam, helping the toothpaste to reach all the tiny crevices of your teeth. Binders and thickeners also prevent the ingredients from separating, while flavouring and sweeteners keep the natural bitterness of toothpaste at bay, leaving you with a minty fresh taste. There's also fluoride in toothpaste, which helps to strengthen the enamel on your teeth. Each brand then adds its trademark combination of antimicrobial, tartar control and/or whitening agents.

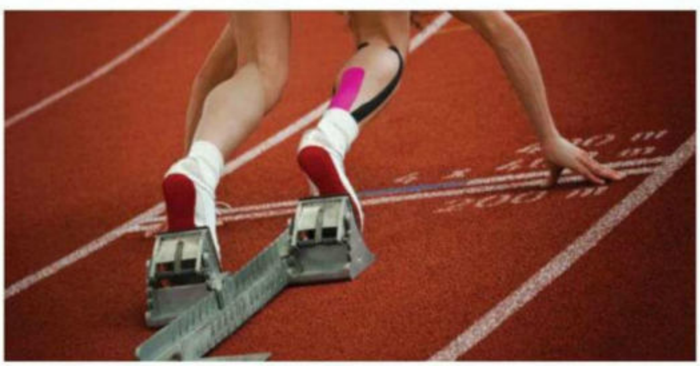
Toothpaste is a mixture of powdered solids and various liquids, so it's neither a liquid nor a solid. Chemists would argue that toothpaste is a colloid (like milk or ink): a mixture where tiny particles of one substance are dispersed evenly into another without separating out.
Alexandra Cheung

What exactly is Kinesio tape?

Kevin Dunn

Kevin isn't the only person curious about this neon athletic tape, which adorned the bodies of many an Olympic athlete at the 2012 Games. The elastic, adhesive cotton tape, which was developed by Japanese chiropractor Dr Kenzo Kase more than 30 years ago, claims to be superior to conventional athletic tape because it provides support without restricting movement.

The greatest benefit of the tape, according to Kinesio, is the way it 'lifts' the skin to reduce pressure, relieve swelling and improve the flow of blood and lymphatic fluids. In fact, Kinesio tape was originally used to treat patients suffering from lymphoedema, a chronic and painful swelling of the arms and legs. Kinesio offers seminars to train physical therapy practitioners in the proper application of the tape for a variety of conditions ranging from knee injuries to headaches. Although many athletes and therapists swear by the tape's effectiveness, there is little science to back Kinesio's claims. One study found it improved the range of motion for certain shoulder injuries, but most scientists attribute Kinesio's widespread use predominantly to a placebo effect.
Dave Roos



It's as easy as riding a bike... yet cycling actually requires some very complex behaviour

Why don't we forget how to ride a bike?

Daniel Bauer

Recent neuroscience research has shed some light on why memories of complex co-ordinated activities like riding a bike are resilient. According to one theory, different parts of memories are scattered throughout the brain. When we activate a memory, other memories partly stored in the same locations, such as how to pedal, could be reinforced. Another idea is that a nerve cell called the molecular layer interneuron interacts closely with the cerebellum, a part of the brain that helps us do complex things. This cell takes memories encoded in electrical signals coming out of the cerebellum and somehow makes them very persistent.
Michael Simpson

© Thinkstock; NASA

How is decaffeinated coffee produced? Find out on page 84

BRAIN DUMP

Because enquiring minds want to know...

Why is cling-film so sticky?

Find out on page 85

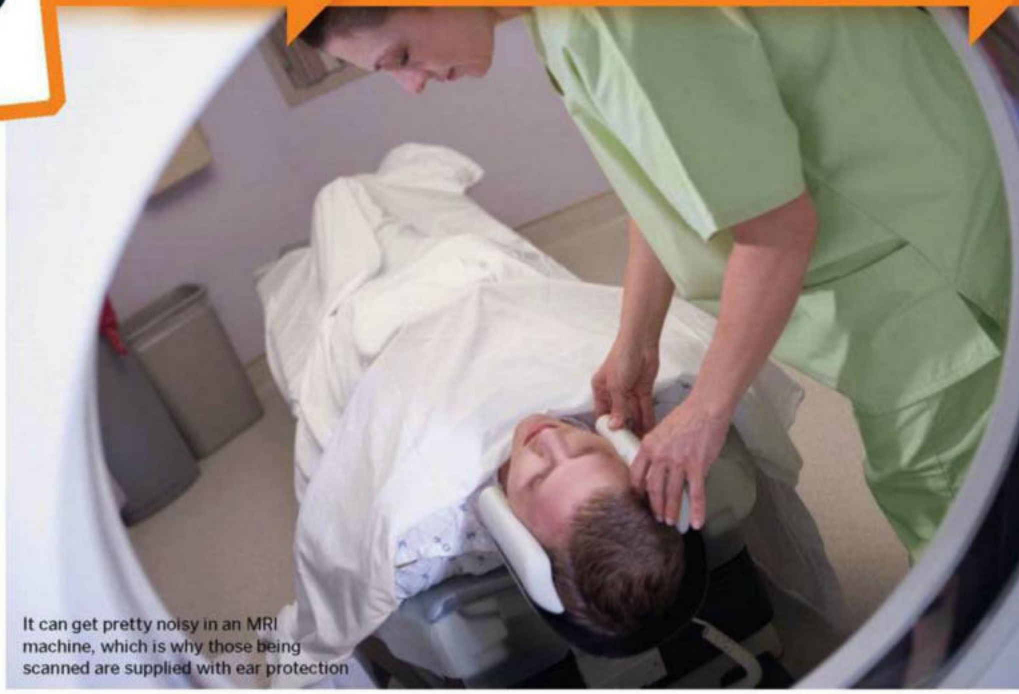
Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

What's the loud banging that CT scanners make?

Susie Lansdowne

Computerised tomography (CT) scanners usually produce very little noise – you're probably thinking of the loud bangs typical of MRI (magnetic resonance imaging) scanners. MRI scanners map your insides by measuring how your tissues respond to changes in a powerful magnetic field. This magnetic field is created by running a high-voltage electrical current through coils of wire. To produce shifts in the magnetic field, the electric current comes in pulses which oppose the field. This causes the coils to contract and expand ever so slightly, resulting in a rapid knocking or hammering noise. Depending on the strength of the magnetic field, this noise can be as loud as 120 decibels – which is equivalent to a jet engine!
Alexandra Cheung



It can get pretty noisy in an MRI machine, which is why those being scanned are supplied with ear protection

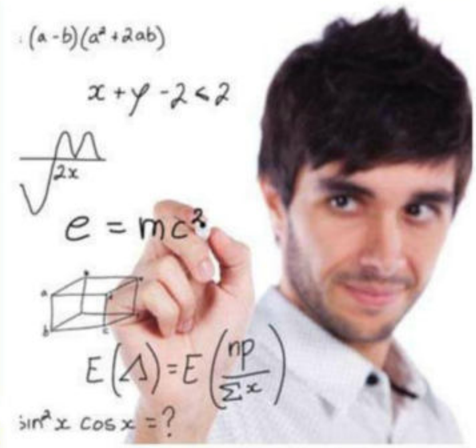
To reduce the caffeine content in coffee, the beans get a long bath

How is coffee decaffeinated?

Paul Branson

To make decaf coffee, companies soak green coffee beans in hot water (70-100 degrees Celsius/160-210 degrees Fahrenheit) to soften them and draw out the water-soluble caffeine molecules. Depending on the method, the water bath might contain a chemical solvent like methylene chloride or ethyl acetate that clings to the caffeine molecules and then evaporates out of the solution.

Another method soaks the beans under very high pressure and temperature, using liquid CO_2 as a 'natural' solvent that bonds with the caffeine. The most natural method uses only water treated with coffee oils to draw out the caffeine gradually in batches. Once the green coffee liquid is at least 98 per cent caffeine free, it is soaked up again by the coffee beans, which are dried, roasted and bagged for sale.
Dave Roos



Why do paper cuts hurt so much?

Stephen Ireland

Paper can cut your skin as it is incredibly thin and, if you were to look at it under a high-powered microscope, it has serrated edges. Critically though, a sheet of loose paper is far too soft and flexible to exert enough pressure to pierce the skin, hence why they are not a more frequent occurrence. However, if the paper is fixed in place – maybe by being sandwiched within a pack of paper – a sheet can become stiff enough to attain skin-cutting pressure. Paper cuts are so painful once inflicted as they stimulate a large number of pain receptors – nociceptors send nerve signals to the spinal cord and brain – in a very small area due to the razor-type incision. Further, because paper cuts tend not to be very deep, bleeding is limited, leaving the pain receptors open to the surrounding environment.
HIW

Why are some people just good at maths?

Fredrick Pleat

Research using fMRI scanners, which can measure brain activity in real-time, has shown the parietal cortex is involved in most of the mathematical heavy lifting. This is the part of the brain near the front and top, just above your forehead. The right side of the parietal cortex is mainly involved with simple counting and gauging relative amounts, whereas the left handles operations with more precision, such as arithmetic. Research in 2012 has shown that our ability with some maths tasks depends heavily on how well the two sides of the parietal lobe can communicate with each other. Subtraction is one such task, which may be why subtraction generally feels harder than addition. Maths ability is also correlated to some extent with autistic traits, but it isn't clear yet whether this is because both are caused by the same genes or because the poor social skills shown by people with autism and Asperger syndrome make subjects such as maths, physics and engineering more attractive to them. Numeracy and literacy go hand in hand for most people, so it may simply be that those who are good at maths are more intelligent.
Luis Villazon

How does cement bind bricks together?

Tim Henshaw

Cement is a mixture of dicalcium silicate and tricalcium silicate, together with ten per cent calcium sulphate and other compounds added to control the setting time. When you add water it reacts to form a complicated crystal structure. The crystals penetrate into the tiny pores and grooves in the bricks as they grow and then set hard to lock them in place. Unlike lime mortar, cement isn't drying out or reacting with the air as it sets: cement actually sets slightly better underwater as it's reacting chemically with the water itself. Cement sets hard in about eight hours, but continues to get stronger over time as more of the material crystallises. After three months, it's five times stronger than freshly set cement.
Luis Villazon

How can shale gas mining cause people's taps to catch alight?

Michael Murnane

Shale is a very impermeable rock, so to extract methane gas within it, mining companies pump water at high pressure down a borehole to force cracks in the rock to widen. This can sometimes drive the methane up into shallower rocks containing groundwater. When this water is extracted it retains some dissolved methane, which usually leaves the solution in the pipes. In extreme cases, you can hold a lit match to the stream of water coming out of a tap and the methane will set alight.
Luis Villazon

Why is the sea bluer in the Caribbean?

Laura Moore

When photons in sunlight strike water they collide with the atoms that make up H_2O molecules and with floating particles or phytoplankton. The impacts send the photons scattering in all directions. Essentially, the colour of those that are scattered upwards contributes to the hue that we see from above. A range of wavelengths of light is scattered by floating particles, from the longest (ie red) to the shortest (ie blue and violet).

If phytoplankton are abundant in a certain area, the chlorophyll they contain will scatter green light just like it does in land plants, giving water a greenish-turquoise tint. The Caribbean contains relatively few suspended particles or phytoplankton. Hence, the majority of light scattered to the surface is at short blue wavelengths. This effect is exaggerated when cloudless blue sky is reflected on the ocean.
Michael Simpson

What makes clingfilm sticky?

Sara Kamprad

As you peel a piece of clingfilm (also known as food wrap) off the roll, some of the electrons from one layer are pulled onto the other layer, producing areas of positive and negative charge. Clingfilm is made of thin plastic, a good insulator, ensuring that it holds an electrostatic charge for a while. When the clingfilm touches another insulating surface, such as glass, the charged clingfilm is attracted to the opposing charge of the surface. But don't bother trying to stick clingfilm to a conducting material such as a metal bowl – its electrostatic charge dissipates so the clingfilm quickly loses its sticking power.
Alexandra Cheung

What science is behind the term 'squeaky-clean'? Find out on page 86

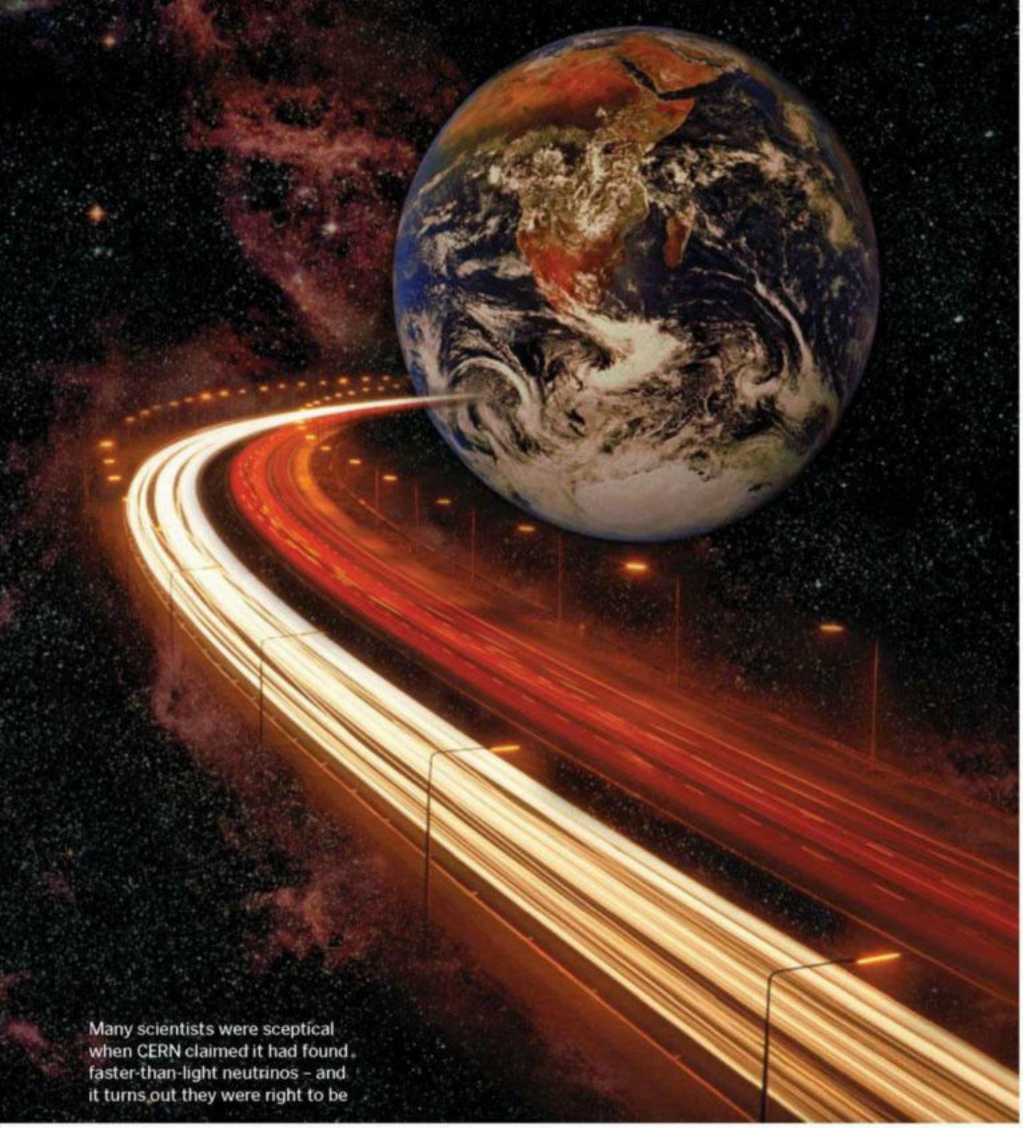
Could Mars harbour life?
Find out on page 87

Want answers?
Send us your questions using one of the methods opposite and we'll get them answered

Could we live in another universe if the speed of light was different?

Will

The speed of light is a sort of cosmic speed limit - nothing can travel faster than 299,792,458 metres (983,571,056 feet) per second. In 2011, a team of scientists at CERN announced beams of neutrinos had beaten the speed of light by about 60 billionths of a second. Under Einstein's theory of special relativity, if something can move faster than the speed of light, it can also travel back in time. Physicists have based a lot of big theories on the value of the speed of light, so if CERN scientists were accurate, there could have been major implications. However, in June 2012, after extensive testing, the researchers confirmed the anomalous result was down to a fault in the fibre-optic timing system. Remember, these theories are just a way of explaining how the universe works - it was working by itself long before Einstein et al came along to explain it. Life would still go on without theories.
Shanna Freeman



Many scientists were sceptical when CERN claimed it had found faster-than-light neutrinos - and it turns out they were right to be

Why must fridges be properly disposed of?

Danielle Keller

Refrigerators, freezers and some air conditioners all contain chemicals called refrigerants. Most refrigerators made before 1990 use chlorofluorocarbon (CFC) refrigerant, which depletes the protective ozone layer of the Earth's atmosphere. CFCs are also potent greenhouse gases, accelerating the rate of climate change. Even newer refrigerators, which run on ozone-safe hydrofluorocarbon (HFC), need to be disposed of carefully, because HFCs are still greenhouse gases. Depending on the age of your refrigerator, it might also contain foam which is made with CFCs, used oil with ozone-depleting substances, plus wires and switches containing toxic mercury. Recycling facilities can safely remove these components before reusing the fridge's plastic, metal and glass.
Dave Roos

What is meant by the saying 'squeaky-clean'?

Alex

When you are washing up a wineglass, your fingers slide over the surface of the glass because a thin film of grease acts as a lubricant. This grease comes from your food, but also from the oil naturally occurring in our fingers. As you wash the glass, the detergent removes this grease and your fingers don't slide so easily any more. At a microscopic level, tiny ridges on your skin catch and release against surface roughness on the wineglass. This makes the vessel vibrate at high frequency and it's this that creates a squeaking sound which tells you the glass is now clean.
Luis Villazon

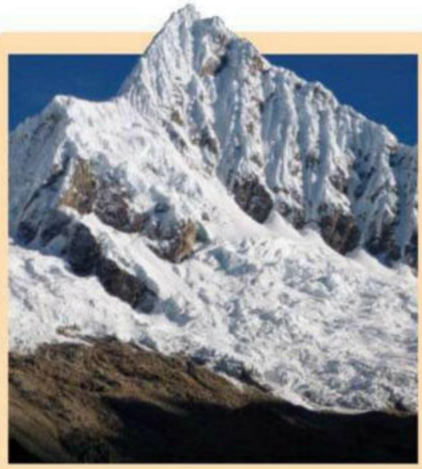
The Curiosity rover only touched down on Mars on 6 August, but it has already made some amazing discoveries, including evidence of past flowing water

Could the Red Planet have once been able to support life?

Rowan Renworth

We've always wondered if there is life on Mars, and while we have found evidence of water ice, finding proof of life continues to elude us. But that doesn't mean there aren't possibilities. We're not talking about little green men though – it's more like microbial or bacterial life. The intense radiation that bombards the planet would probably make life on the surface next to impossible, and now any liquid water would exist below the surface where it's warmer. There have been hints. For example, we discovered that the levels of methane in Mars's atmosphere may have micro-organisms beneath the surface as a source. A few years ago, a multinational team of scientists came up with a hypothesis. When the ice cap on Mars's south pole thaws in the spring, there are visible dark patches called 'spiders'. While some believe these patches are due to eruptions of gas and sand, they could be from photosynthetic micro-organisms that live in a layer of liquid water. They dry and turn black when the ice melts, exposing them. With the Curiosity rover currently analysing the Red Planet, hopefully we'll get more concrete evidence.

Shanna Freeman



What is the natural pressure of air and why does it alter at different altitudes?

Charlie Stubbings

Average air (or atmospheric) pressure at sea level is 1.03 kilograms per square centimetre (14.7 pounds per square inch). Although it's easy to forget, air molecules all weigh something, and their combined weight pressing down is what causes this pressure. At sea level, the column of air above you weighs about a ton. As you gain altitude, the number of air molecules above you decreases, and therefore so does the air pressure. The lowest atmospheric pressure on Earth can be found at the summit of Mount Everest, where it's just 0.3 kilograms per square centimetre (4.4 pounds per square inch).

Alexandra Cheung

It might look like a wasp, but this is actually a hoverfly (one set of wings), so it has a higher-pitched buzz

Why does the buzz of a fly and a wasp differ?

Laurence Batten

The buzzing sound of a fly or wasp is created by the vibration of the insect's wings. A common housefly flaps its wings 200 times per second. That means it completes a flapping cycle – wing up, wing down, wing up – 200 times every second. That translates into a frequency of 200 Hertz. The human ear interprets frequency as pitch. For example, middle 'C' on the piano vibrates with a frequency of 261.6 Hertz. The higher or lower the frequency, the higher or lower the pitch. Four-winged insects like wasps and bees flap their wings at a slower frequency than two-winged flies, resulting in a deeper buzz.

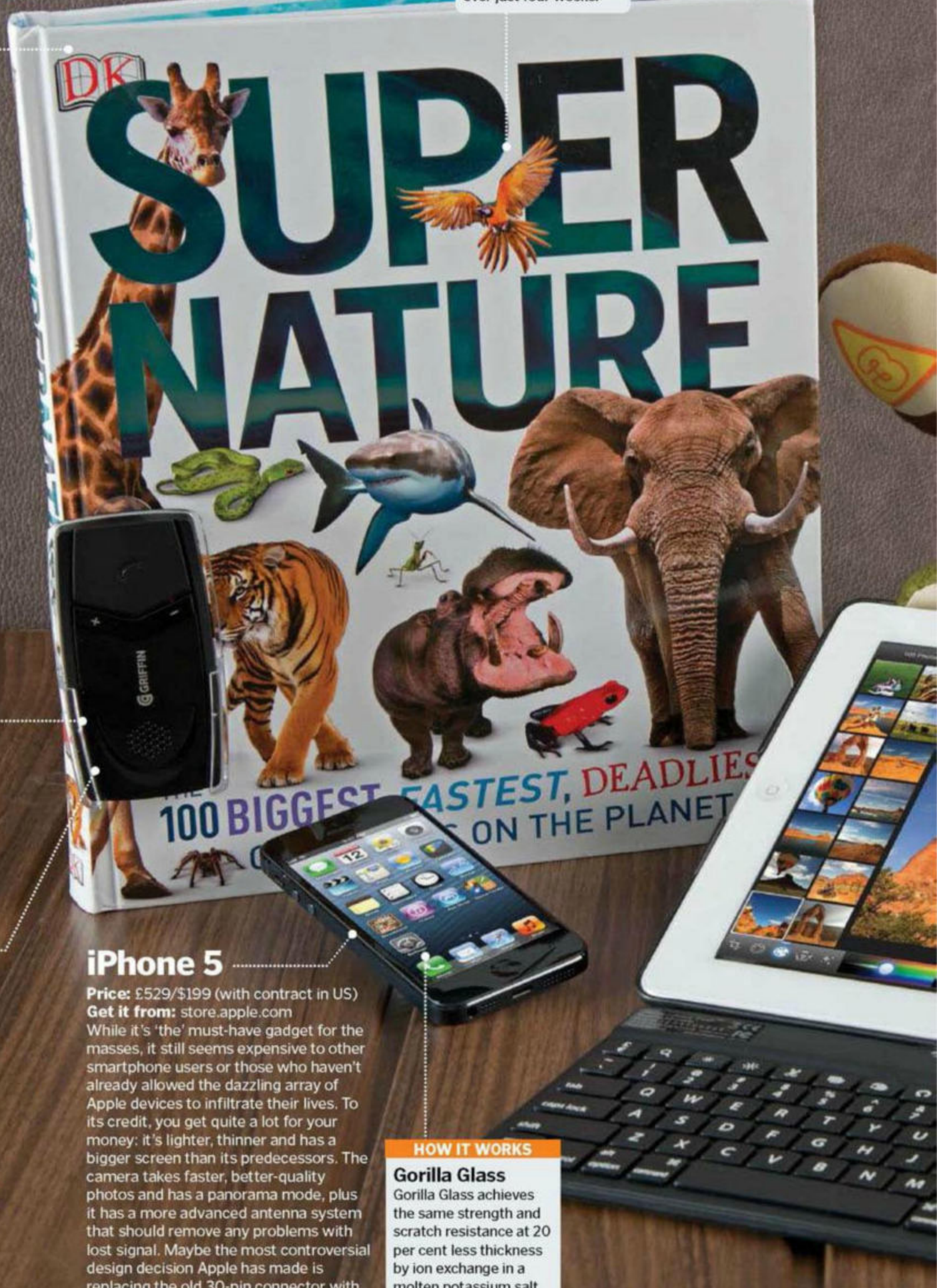
Dave Roos

Why does holding your hand under water help if you burn yourself?

Aaron Roberts

When you scald your hand with boiling liquid or burn it with a hot object, your first reaction should be to pull it away. Just because your body is no longer touching the heat source, though, doesn't mean the burning stops. Layers of skin that were just exposed to a high temperature take time to cool down and a lot of harm can still be done to cells by the residual heat. Holding burned skin under a tap or submerging it in a bowl of cool (but not freezing) water reduces the temperature quicker, thereby potentially limiting the damage.

Michael Simpson



Super Nature

Price: £18.99/$24.99
Get it from: www.dk.co.uk
'The 100 biggest, fastest, deadliest creatures on the planet' is a pretty compelling pitch and, in the tradition of DK's back catalogue, it's hard to put down *Super Nature* once you've opened it. It's a massively image-led hardback tome, but it's most certainly not without substance. Short bursts of text rattle off facts and figures of the world's smallest, most poisonous and strongest bite, and much more, with side-by-side comparisons with more mundane animals, including humans. It's illustrated by cutaway images, annotations and pretty much everything you need to keep anyone from five to 105 occupied.

HOW IT WORKS

Cicada life cycle
The North American periodical cicada spends 17 years underground, before emerging to mate, lay its eggs and then die over just four weeks.

HOW IT WORKS

Rechargeable cell
Rechargeable batteries are integrated into a wide range of electronic devices today. Nickel cadmium is the active chemical typically used and its reactions are electrically reversible.

SmartTalk Solar

Price: £49.99/$69.99
Get it from:
www.griffintechnology.com
Pair the device, lick the sucker cups on the back, slap it on the windscreen and you're away. Almost. Griffin's SmartTalk Solar mobile hands-free technology has a feature that ups the ante over many rival technologies: a solar panel on the reverse enables it to charge via the sunlight through your windshield. If you're not lucky enough to live in California or sunnier climes, you can always use the 12V adaptor. It certainly feels more robust than other hands-free kits and the single chunky call button is a godsend to those who are all thumbs, fumbling anything minute enough to require dainty prodding, though this device does come with a slightly steeper price tag than competitors.

iPhone 5

Price: £529/$199 (with contract in US)
Get it from: store.apple.com
While it's 'the' must-have gadget for the masses, it still seems expensive to other smartphone users or those who haven't already allowed the dazzling array of Apple devices to infiltrate their lives. To its credit, you get quite a lot for your money: it's lighter, thinner and has a bigger screen than its predecessors. The camera takes faster, better-quality photos and has a panorama mode, plus it has a more advanced antenna system that should remove any problems with lost signal. Maybe the most controversial design decision Apple has made is replacing the old 30-pin connector with its new Lightning port. Arguably this was bound to happen at some point though, so it's far from a deal-breaker.

HOW IT WORKS

Gorilla Glass
Gorilla Glass achieves the same strength and scratch resistance at 20 per cent less thickness by ion exchange in a molten potassium salt bath. It's been used in several iPhone models.

Bábógbaby

Price: £29.99/$50
Get it from: www.babogbaby.com
Want to learn Irish, Welsh or Scottish Gaelic? If you're older than the six month-plus range this early learning teddy bear is recommended for, then you'd be better off investing in a few CDs and some lessons. Otherwise, let us introduce you to Bábógbaby, one of the cutest ways to learn the very basics of a Gaelic language. Each teddy features ten numbers, shapes and colours stitched onto various parts of its body, which are vocalised via a small speaker when the appropriate part is squeezed. Understandably it has won several awards, not just for the promotion of niche languages, but by being an effective way to encourage a child to practise speaking a different language from a very early age.

HOW IT WORKS

Learning aid
Infants who are aged between one and three years learn sentences by looking for a common pattern of sounds, distinguishing breaks between words when they hear an unfamiliar pattern.

Freedom i-Connex Combi

Price: £79.99/$99.99
Get it from: www.freedominput.com
There are a few devices of this type on the market, but they don't come much more competitive than this one from Freedom. The i-Connex Combi is thin, light and effortlessly simple to use. The segmented cover that protects your screen flips back over the hard shell case, into a clever bit of origami-folding that allows an iPad 2 or the new iPad to stand in portrait or landscape. In the back, there's a USB-chargeable, portable Bluetooth keyboard that, despite its weight and size, has a comparable tactile response to that of a desktop keyboard. It pairs to multiple devices too, so you can use it with an iPhone, Android devices and anything supporting HID-compliant keyboards. Its features and ease of use alone make it a compelling purchase for iPad-dependent commuters, and you can spend a lot more than what you pay here on similar products.

HOW IT WORKS

HID compliance
A human interface device (HID) works by defining itself simply using an HID descriptor that is saved on to the device and presented to the operating system once it's connected.

HOW IT WORKS EDITOR'S CHOICE AWARD

APPS OF THE MONTH

Brought to you by **Apps Magazine**, your essential guide to the best iPhone and iPad apps available on the Apple App Store

iPad: littleBIG History

Price: £2.99/$4.99
Developer: VariaMedia GmbH
Version: 1.0
Size: 36.8MB
Rated: 4+
This app is the story of our universe from the Big Bang to the predicted collapse of the Sun, and everything in between. It's a big-picture approach that some may find a little too broad for their tastes. However the strength of this timeline is in its visualisation of information. Using the shuffling tiles at the bottom of the screen, the highlighted streams of time that represent the life span of empires and important figures in our history are both humbling and inspiring. A must for history fans.

Verdict:

iPhone: Teach Me Sushi

HOW IT WORKS EDITOR'S CHOICE AWARD

Price: £2.99/$4.99
Developer: Jake Davidowc
Version: 2.1 **Size:** 499MB **Rated:** 4+
If you're coming at sushi and sashimi making fresh and want to get the basics, this is a great place to start. Mostly consisting of video tutorials, there are no hard and fast recipes, as the focus is on letting you experiment and find your own way of combining the key staples yourself. Bon appétit!

Verdict:

Gaming PC systems

Which of these three setups is the top dog for gaming?

PowerGlide Extreme 6700

Price: £1,249/$N/A
Get it from: www.pcspecialist.co.uk

If you have a limited amount of space an all-in-one (AIO) PC may be for you. It combines a 96-centimetre (24-inch) hi-def monitor with desktop components that can be mounted on to a wall using the provided brackets. It includes the meaty GeForce GTX 670 featured in the other two systems, an i5-3570K CPU, 8GB RAM, a hard disk drive/SSD combination – which means booting is super-silent and fast too – plus it will match the desktop for performance. This AIO has a multitouch screen, which means you can gesture using multiple digits to navigate within the Windows 8 interface. It's a novel feature for a gamer, but it does make this system a multimedia all-rounder and a more compelling choice for a dual-use, playtime and work setup. There's quite a bit of flex around the bezel and the system requires no less than three power supplies. The main issue, however, will be the price, but some will be willing to pay the extra for its compactness.

Verdict: 3/5

Vortex III 670GTX

Price: £999/$N/A
Get it from: www.pcspecialist.co.uk

Gaming laptops used to be beyond the reach of the average PC gamer, but the market has changed. There doesn't seem much in the way of compromise here: the build quality is superb and its tactile keyboard yields very little under typing pressure. Like the desktop it comes with a two-year warranty and Windows 8; unlike the desktop it boasts a 43.9-centimetre (17.3-inch) full-HD screen. It's also furnished with a GeForce GTX 670m, the mobile equivalent of the desktop 670, 8GB of 1,600MHz RAM and an i7-3610QM, a beefy mobile CPU that turbos up to 3.3GHz on each of its four cores under big loads. Despite the performance of the mobile graphics GPU coming an expected second to the desktop, this portable gaming system still spits out polygons faster than the eye can see – literally, with liquid-smooth rates of 50-plus frames a second quite common on recent big titles. For the price, this portable could easily convert the most hardcore desktop advocate.

Verdict: 5/5

Vengeance CM690

Price: £999/$N/A
Get it from: www.pcspecialist.co.uk

The PC gamer's go-to is the classic desktop tower and, while this one is hardly bling-tastic, it's housed in a sturdy and capacious black Cooler Master chassis. Component quality continues within: a 650W Corsair PSU powers GeForce GTX 670 graphics, 8GB of fast DDR3 RAM and the heart of the system, a 4.4GHz i5 processor. Couple that with Windows 8 loaded on to a 120GB SSD (with a 1TB drive for storage) and it's one of the fastest booting machines we've encountered. Does that translate into gaming glory though? It certainly does: the trinity of powerful CPU, RAM and graphics made short work of all the benchmark and gaming tests we threw at it. Given the nature of the PC gaming market, it's not likely to become obsolete any time soon and, this being a desktop system, there's plenty of room for expansion. Thumbs down for the lack of wireless network adaptor, and you'll need to buy a screen too, but it's a powerful gaming PC that, despite the drawbacks, is worth its price.

Verdict: 4/5

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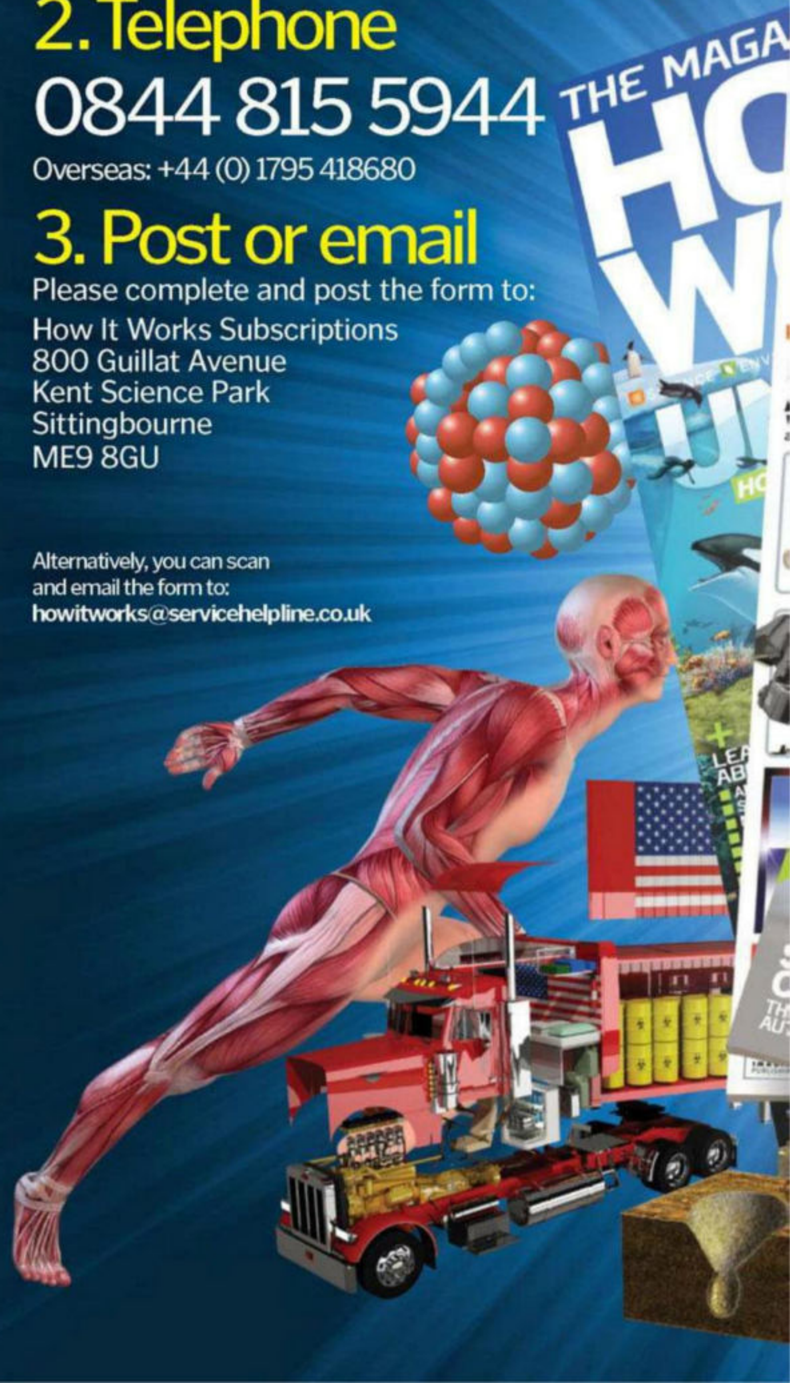

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Pilot a hot-air balloon

How to launch, fly and land one of these huge flying contraptions

1 Setting up
Firstly the burner unit must be attached to the basket, followed by the balloon envelope. Once laid out, the envelope needs to be partially inflated with a large fan. The burner is then switched on, heating up the air and fully inflating the balloon.

2 Launch
For passengers to get into the basket safely, crew members must hold the basket down. When ready, the crew then releases the balloon and the pilot fires a steady flame to get off the ground.

3 Going up
By opening a propane valve, the amount of gas being fed into the burner is increased to gain altitude.

4 Staying in control
To change direction the pilot must ascend or descend in altitude to catch specific wind flows. To travel quickly the pilot will ascend to a high altitude, or to slow down, descend.

5 Landing
Landings require the pilot to gradually release air pressure by opening a parachute valve. Touching down involves a staggered series of bumps.

Brew your own beer at home

Make some tasty ale from the comfort of your own home by following this simple step-by-step guide

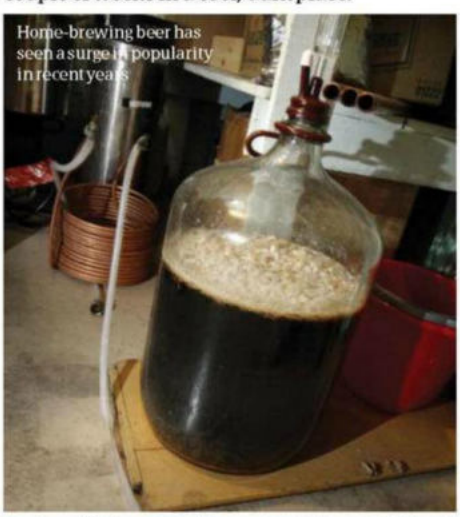
1 Brewing
Start by mixing 2.7 kilograms (six pounds) of unhopped malt extract with 64 grams (2.25 ounces) of hops and then add them both to a large pan (the bigger the better) of boiling water. This will sterilise the extract and help release the hops' flavourings.

2 Fermenting
Once the mixture (which is known as wort) is hot and thoroughly combined, it can be removed from the heat, cooled and siphoned into a fermenter. Once in the fermenter, extra water should be added – until the total mix reaches roughly 19 litres (five gallons). A single packet of liquid yeast is also added now.

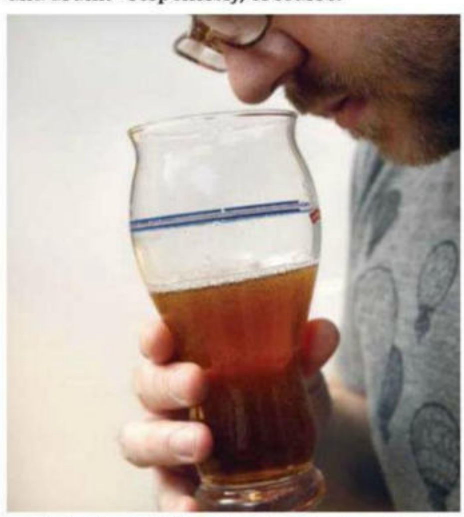
3 Prime time
The fermenter can then be topped with an airlock. The airlock prevents the wort, which is easily contaminated at this stage, from being infected with bacteria. Once the airlock is in position, the wort can be left to ferment for a couple of weeks in a cool, dark place.

4 Bottling it
Once the beer is fermented, the mixture can be removed from the fermenter and siphoned into a sterile container for bottling. In this container two or three cups of priming sugar – eg corn sugar – should be added. The mixture can then be bottled and capped.

5 Time to mature
The beer should now be left for three more weeks. This last fermenting period will involve the remaining yeast breaking down the priming sugars and creating carbon dioxide, which adds fizz to the beer. After this period has elapsed, the bottled beer can be chilled and drunk – responsibly, of course!



Home-brewing beer has seen a surge in popularity in recent years



NEXT ISSUE
- Skim a stone
- Build your own go-kart

If you want to brush up on your polishing skills, you really need to invest in the right equipment

Polish your shoes

Discover how to get a military-grade shine on all your leather footwear

1 Prep
To avoid getting polish all over your carpet, start by grabbing some newspaper and spreading it over the working area. Next, soak a rag in cold water and thoroughly clean off any dirt on the shoes. Finally, if the footwear has become damp while cleaning, leave to dry before moving on.

2 Application
Next, grab a shoe and liberally coat its surfaces with a large quantity of polish. This should be done with a dedicated shoe polish brush, which tends to be a small circular affair with an elongated handle. It's critical to carefully match the polish colour with that of the leather for the best results.

3 Remove the excess
Once the shoe is totally covered with polish, pick it up from the inside, so you don't get polish on your hands. Take a horsehair shine brush. These brushes are roughly rectangular in shape and are gripped from the rear rather than by a handle. Rigorously scour the shoe until all excess polish is removed.

4 Heel and toe
Next take a cotton wool pad, dip it in some cold water and squeeze so it is no longer sodden but just damp. Apply a little polish to it before wiping it over the heel and toe of the shoe in small circular motions. Repeat this step several times until satisfied, using a few cotton wool pads.

5 Wax
Finally, it's time to add some wax, which ideally should be applied with a dedicated wax brush. Shoe wax is good for both increasing shine and also creating a protective layer between the leather and the elements so your smart footwear lasts for longer.

electronics and follow the manufacturer's instructions.

TEST YOUR KNOWLEDGE

ENJOYED THIS ISSUE? WELL, WHY NOT TEST YOUR WELL-FED MIND WITH THIS QUICK QUIZ BASED ON THIS MONTH'S CONTENT?

1 How large is the Forbidden City in square metres?
A: ____

2 What was the passage leading up to a Mycenaean tholos tomb called?
A: ____

3 How heavy is aerographite in milligrams per cm³?
A: ____

4 When did the Sydney Opera House first open?
A: ____

5 How heavy is the WISE telescope in kilograms?
A: ____

6 What is the top speed of the MiG-29 in miles per hour?
A: ____

7 What was the average weight of Stegosaurus?
A: ____

8 In which year did Joseph Swan first show his cellulose fibre light bulb?
A: ____

9 When was the Slinky spring toy first sold?
A: ____

10 How much did the Necker Nymph sub cost to build?
A: ____

ENTER ONLINE

at **www.howitworksdaily.com** and one lucky reader will win a set of models of three of the most iconic aircraft, including a Spitfire Mk1a

> ISSUE 39 ANSWERS
1. Pulse-Doppler **2.** 1512 **3.** 3.5mn **4.** 2,200kg **5.** Oak
6. Tokyo **7.** 90% **8.** 630mph **9.** £534m **10.** 19.2 trillion

INBOX

Feed your mind. Speak your mind

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Get in touch!

We enjoy reading your letters every month. So keep us entertained by sending in your questions and views on what you like or don't like about the mag.

FANTASTIC PRIZE FOR LETTER OF THE MONTH!

WOWee ONE™

WIN A WOWEE ONE PORTABLE SPEAKER

This issue's top letter wins a WOWee One Classic portable speaker. This turns any surface into a bass amplifier using gel technology, and is compatible with all iDevices and other mobile gadgets.

Win! A WOWee One portable speaker

Triremes needed up to 170 rowers to get around – a man for each oar

© Alex Pang

Letter of the Month

Triremes and tribulations

Hello,
I recently bought your bookazine **How It Works Book Of Incredible History**. I was wondering about the illustration of the Greek trireme warship. The cutaway shows the rowers seated on what is described as the thranitai deck. Rowers must be seated so as to pull the oar handles in towards themselves, so the boat moves in the opposite direction to that they are facing, and so implies the vessel's direction is towards the aft portion of the ship. However, assuming the front of the vessel is the end with the battering ram – and the wind in the sails confirms this as the direction of the vessel – the rowers therefore would be rowing the ship backwards. Perhaps the rowers had to turn around on their seats to be able to move the vessel in the other direction when they wanted to use the battering ram? Please let me know – just to satisfy my curiosity!
Martin Leeson

Hi Martin,
Given the position of the rowers and the shape of the sails, if the rowers pulled the oars towards them it would indeed work against the wind and the direction of the vessel. The rowers did need to turn around in their seats to row in the direction of the battering ram, but let us offer another possibility: the rowers are positioned to act as a brake. If the trireme needed to stop suddenly, the sails were furled and the rowers pushed hard to slow the ship. For your hawk-eye observations, have a prize on us!

Wrong type

Hi HIW,
Congratulations on the excellent mag. Having over 30 years' experience in the typewriter business I wish to make an amendment to 'Typewriter tech' (issue 38, page 88). When a key is pressed the typehead causes the ribbon to lift then hits the ribbon, transferring the impression onto the paper. The ribbon does not ink the typehead. There is a two-colour switch on most typewriters: in position black (or blue) the machine uses the top of the ribbon, while in position red it uses the bottom half. Position white (in between) cuts out the ribbon altogether and is used for cutting wax stencils for use on an ink duplicator, such as Gestetner or Roneo. Also, just thought that you may like to know that the longest word that can be typed on the top line of a typewriter is actually the word 'typewriter'. Keep up the good work!
Kind regards,
Colin Evans

We should have made the distinction, of course, between antique typewriters that use the pressure of the bar pressing into the ink ribbon and the modern machine typewriters you are referring to, but thanks for writing in and sharing your expertise, Colin. And what a great bit of trivia!

Fact-packed

Afternoon How It Works,
Let me congratulate you on an amazing magazine; it's packed full of interesting facts and information. Once I start I can't stop and it allows me to reel off facts and figures to friends and family who are amazed at my intellect... I don't tell them the source of my information is your mag – why shatter the illusion? Anyway, it's so good that I was going to subscribe, but my girlfriend got there first!
Paul Francis, Swindon, UK

Born-again astronomer

Dear HIW,
I just thought I'd take the time to write you an email thanking you for your excellent space articles. I loved watching the stars as a little boy and staring at the Moon through my telescope, but I stopped my budding hobby in my teens. Your Space section has rekindled my passion for astronomy and the recent article 'Birth of the Solar System' [issue

38, page 54] finally prompted me to invest in a good telescope, just to see how the Solar System has been getting on without me checking in on it for the last 20 years. It hasn't changed much! Keep up the good work,
Harry Ridge

Not at all boring

I've just finished your excellent article on drills in issue 38. Four pages on drills… Never thought I'd find that even remotely interesting, even if they were 'mega drills', but the incredible feats of engineering (as well as the cool illustrations and the way the piece was written) had me hooked. It's got me wondering though, could we use one of these drills to bore a hole to the Earth's core? I'm really curious about what it's like down there.
Caroline Cousins


Scientist Eileen Stansbery works on a solar array in NASA's cleanest room
© NASA

Keep it clean

I have a question about the article 'How cleanrooms stay pristine' [issue 38, page 59]. In the photo it shows people with their faces uncovered and wearing glasses. Wouldn't that be considered contaminating the room? Plus, are those special glasses or do they wear them in from the outside? Thank you,
Nancy L McGinnis, Sioux City, USA

Hi Nancy, thanks for your letter. NASA procedure is in fact to use sealed masks over the head to ensure bacteria from breath and any skin cells don't contaminate critical equipment. Those photos show a cleanroom engineer preparing a less sensitive data-handling unit for a photoshoot. Perhaps the picture above will help 'clean up' the matter?

What's happening on… Twitter?

We love to hear from **How It Works'** dedicated readers and followers, with all of your queries and comments about the magazine and the world of science, plus what you'd like to see explained in future issues. Here we select a few of the tweets that caught our eye over the last month.

Lewis Beechey
@LewisBeechey
@HowItWorksmag
'If the cosmos is always expanding, what is it expanding into?' [issue 38, page 83] – the same question hurt my brain the other day

Douglas Gray @Hellboy919
@HowItWorksmag
I just bought the new issue of your fantastic magazine – it really does feed the mind

Dan Burt @mst3kuk
@HowItWorksmag
Have you ever wondered how they make golf balls?

Andy Shelley @Andy2k64
@HowItWorksmag
Died and gone to geek heaven!

Adams Gas @Stu_Adams
@HowItWorksmag
I'm a few mags behind, but I really enjoyed the 'Extracting natural gas' article that appeared in issue 37. Thanks for keeping me factual

Michael Hubbard
@TheHubbard
@HowItWorksmag
I've lost count of how many times I've been featured in the back of @HowItWorksmag 'What's happening on… Twitter?' =)

HOW IT WORKS

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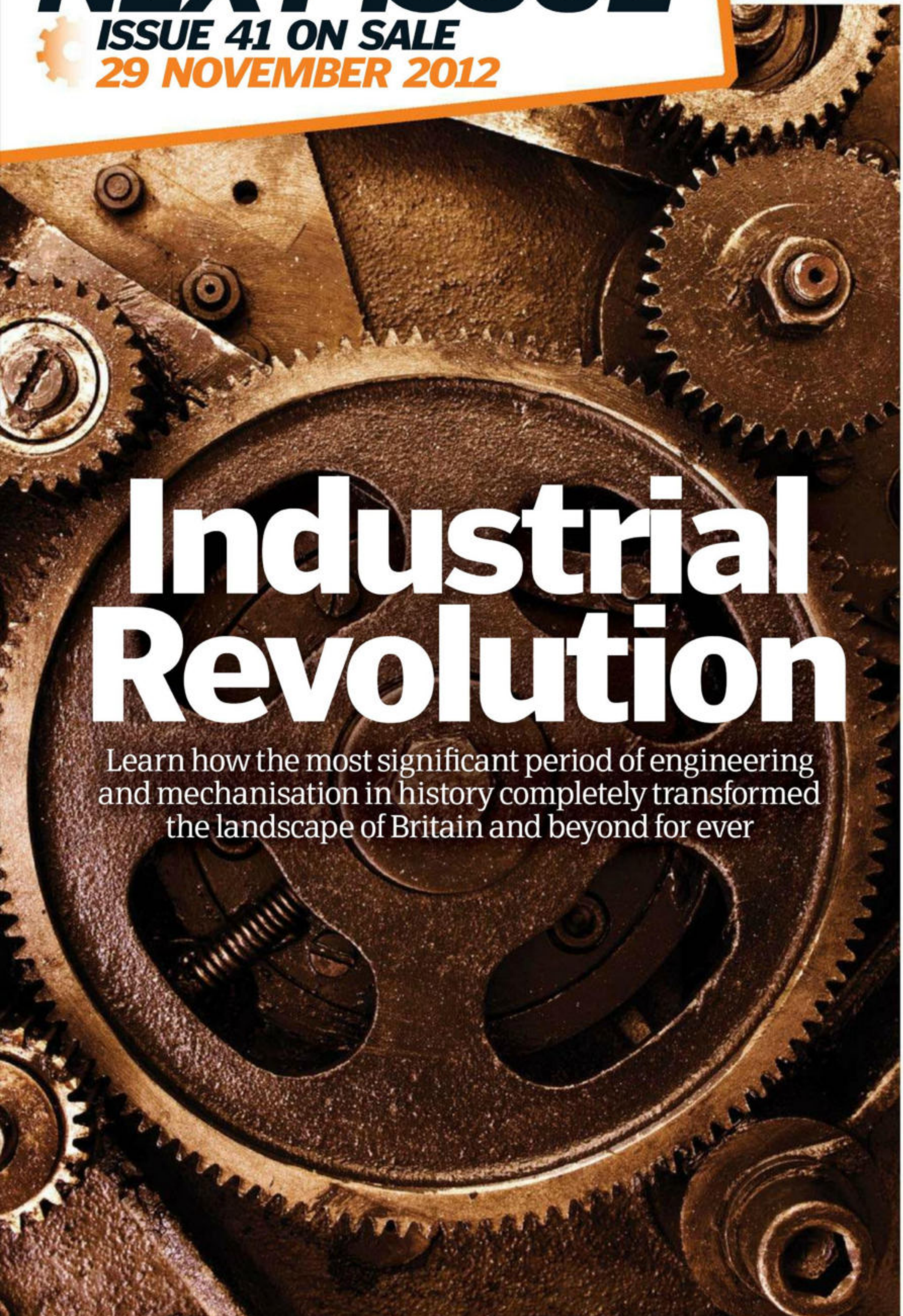

Industrial Revolution

Learn how the most significant period of engineering and mechanisation in history completely transformed the landscape of Britain and beyond for ever

ANSWERED NEXT ISSUE

How was the Hoover Dam constructed?

How do critters use their tongues to catch prey?

Can we stop diseases from going global?

How does melatonin tell us when we're tired?

Where do flowers get their scent from?

+ LEARN ABOUT

- OLED TV SCREENS
- SHARK REPELLENT
- BELT OF VENUS
- CCTV
- PLASMASPHERE
- HARD DRIVES
- MAGNA CARTA
- JOHANNES KEPLER
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